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years, legislation has curtailed some farm tax shelters while enhancing or creating others. For example, the 1969 tax act required some orchard owners and all Christmas tree growers to capitalize and depreciate certain development costs, and it subjected depreciation on some buildings and livestock structures to recapture as ordinary income. The Tax Reform Act of 1976 restricted the tax deductions of limited partnerships investing in feed lot operations. In contrast, the Revenue Act of 1978 created the tax shelter possibilities afforded by single-purpose livestock structures. The 1981 tax act introduced the Accelerated Cost Recovery System (ACRS), which reduced the tax life of most farm equipment from ten to five years.

The Tax Reform Act of 1986 contained provisions that are likely to have substantial impacts on tax shelter investment in agriculture as well as other industries. A major goal of the legislation was to reduce the scope of farm investments that are motivated by income tax incentives rather than economic considerations (Hanson and Bertelsen). Farming activities must now produce a profit in at least three (rather than two) of the last five years in order to satisfy the farming-for-profit test.[1] Long-term capital gains will be fully taxed when realized, and enactment of "passive" loss rules will restrict the ability to offset other income with farming losses. The 1986 tax law replaced ACRS with an approach which will increase the length of time over which capital assets can be depreciated. The investment tax credit has been repealed, and preproduction expenses must now be capitalized rather than deducted if the development period exceeds two years.

A major impact of the provisions in the 1986 law which broaden the tax base is a likely reduction in the kinds of agricultural investment which have attempted to exploit accelerated depreciation, the capital gains exclusion, and current expensing of development costs. For example, Lins, Offutt, and Richardson suggest that investments in livestock breeding and orchards can be expected to fall because of the new passive loss rules combined with the required capitalization of preproduction expenses.[2] However, farm tax shelters are unlikely to be completely eliminated as a result of the 1986 law's changes relating to the measurement of taxable income. For instance, the hobby loss rules have never been a very effective limitation on farm losses, and the IRS does not have the resources necessary to examine every tax return for compliance with the passive loss and other rule changes.

Another important feature of the Tax Reform Act of 1986 which also may affect agricultural investment is the reduction of fourteen marginal tax rates, which ranged from 11% to 50%, to only two rates—15% and 28%. (Some taxpayers will confront an effective rate of 33% because of surcharges.) If high tax rates encourage investment in tax-preferred assets, then farm tax shelter investment can be expected to decline apart from any reduction coming from changes in the new tax law which affect the legality of farm tax shelters. The effect of changes in marginal rates of income taxation on tax shelter investment is discussed in the next section.

Taxation and Investment Choices

Previous research on the economics of income tax preferences provides important theoretical insight into the relationship between tax rate changes and tax shelter investment. In an often-cited 1974 paper, Bailey examined the implications of preferential tax treatment for portfolio choice and investment yields. In his analysis, preferential taxation was exemplified by the failure to tax fully the return on an investment. If the proportion of the before-tax yield which is taxed is a variable α, than $\alpha < 1$ indicates preferential taxation and $\alpha = 1$ implies full taxation. Bailey assumed that the before-tax return r^b decreases as the percentage of an asset's income taxed falls, other things the same, such as risk and transactions costs. In other words, an asset whose income is only partially taxed will command a premium that reduces its gross rate of return, or $\alpha_1 < \alpha_2$ implies $r_1^b < r_2^b$. Furthermore, competition will equalize after-tax rates of return r^a among individuals facing a given marginal tax rate t, where $r^a = r^b(1 - \alpha t)$.

In Bailey's analysis, an individual investor selects the asset yielding the highest after-tax rate of return. The tax-preferred status of the asset selected will depend on the investor's marginal tax bracket. There exists a "break-even" tax rate t^*, which equates the after-tax yields from any two assets with before-tax returns of r_1^b and r_2^b, with $r_1^b < r_2^b$ and $\alpha_1 < \alpha_2$. As shown by Galper and Zimmerman, $t^* = (r_2^b -$

[1] An interesting exception is that activities that consist primarily of breeding, training, showing, or raising horses need show a profit in only 2 out of the last 7 years (U.S. Department of Treasury 1987).

[2] However, the capitalization requirements with respect to animals have been repealed beginning in 1989.

$r_1^b)/(\alpha_2 r_2^b - \alpha_1 r_1^b)$. The implications for investment choice are straightforward. An investor facing a tax rate above t^* should choose the asset whose gross return r_1^b is relatively low but which yields the higher net return because of more preferred tax treatment (low α_1). Similarly, taxpayers facing an even higher tax rate should hold even more preferentially taxed assets, other things constant.

Bailey's general conclusion that high-bracket taxpayers tend to invest in tax-preferred assets is one of several results obtained more recently by Cordes and Galper, who explicitly investigated the effect of tax rate changes on the amount of investment in partially taxed assets. They outlined a general model in which the economy's fixed stock of physical capital is divided between investments in fully taxed assets (K_f) and tax shelters (K_s), which are defined as investments whose returns are not fully taxed. The gross returns to fully taxed capital (r_f) and tax-shelter capital (r_s) diminish with their levels of usage. The model assumes further that capital is mobile and that investors will allocate their wealth between tax shelter and fully taxed investments so as to equalize the after-tax, risk-free, return to capital. Symbolically, in equilibrium $r_s(1 - \alpha t) = r_f(1 - t)$, where t is the marginal income tax rate and α is the fraction of the return to K_s subject to tax, with $\alpha < 1$.

In the absence of taxes ($t = 0$), capital suppliers require that K_s earn the same return as K_f; that is, r_s must equal r_f or $r_s/r_f = 1$. When taxes exist but are neutral in the sense that all returns are fully taxed ($\alpha = 1$), $r_s(1 - t) = r_f(1 - t)$, which implies that r_s/r_f must again equal unity. In other words, if tax shelters do not exist, the rate of taxation does not affect the allocation of capital between assets in the Cordes-Galper model.

When tax shelters exist and all investors confront the same tax rate, capital market equilibrium implies that $r_s/r_f = (1 - t)/(1 - \alpha t) < 1$. This result requires that the share of capital used in tax shelter activities increase, relative to the capital allocation in the no-tax or neutral-tax case. Given the assumption of diminishing marginal productivity of capital, r_f will be relatively higher and r_s relatively lower in the single tax rate case. Because the relative return r_s/r_f declines as t rises, the model predicts that an increase in the tax rate will increase the amount of tax shelter investment. Once capital markets have adjusted to the higher tax rate, all investors will earn the same net return on investments.

Cordes and Galper show that when multiple tax rates exist, the impact of a tax rate change on tax shelter investment depends on the distribution of potential capital supplies among individuals facing different tax rates. At one extreme, taxpayers facing the top tax rate (t_h) may be willing and able to supply enough tax shelter capital to meet the entire demand, leaving fully taxed assets in the hands of individuals facing lower tax rates. Increasing tax rates across the board or just the top rate can be expected to raise the amount of investment in tax shelters. However, because the before-tax rate of return on tax shelter capital will decline as more is supplied, in equilibrium top-bracket investors will be unable to earn a higher net return on investment than owners of fully taxed capital.

If the top-bracket taxpayers cannot supply all the capital for tax shelters, then a similar sorting of investors by asset ownership is suggested by the model. Individuals facing t_h invest only in tax shelters, those facing a lower tax rate t_m hold both tax-preferred and fully taxed assets, and taxpayers facing a still lower rate t_1 purchase only fully taxed assets. The outcome in this case differs from the preceding one in two respects. The first, which is of primary concern given the focus of this paper, is that an increase in all tax rates will encourage more tax shelter investments, but changing only the top marginal rate does not necessarily affect the amount of tax shelter activity. Second, investors in the highest tax bracket will enjoy a higher net return than they could receive from fully taxed assets. This occurs because the before-tax return on tax shelter assets must be high enough to attract capital from investors in tax brackets lower than t_h. That tax shelters provide opportunities for arbitrage when multiple tax rates exist is often illustrated by the high net return which top-bracket investors receive on state and local government bonds (Goode).

Both the Bailey and the Cordes-Galper analyses suggest that an individual's willingness to supply capital for tax shelter investments varies directly with the marginal tax rate; thus, a tax rate increase generally can be expected to raise tax shelter activity. However, these models are general in the sense that they posit a class of partially taxed assets but they do not explicitly consider all the specific instances of preferential tax treatment. In reality, individuals can choose to invest in agriculture, real estate, oil and gas extraction, corporate stocks, municipal bonds, tax-deferred pension plans, and numerous other real and financial assets whose returns are not fully taxed under the federal (and state) tax laws, especially prior to 1986.

The actual provisions of the tax code must be

examined to determine how the extent of preferential taxation varies by assets or industries. Based on their analysis of the tax laws and investments by individual taxpayers in 1972, Galper and Zimmerman concluded that oil and gas extraction and real estate operators were clearly the most favorably taxed 4-digit subindustries appearing in the S.I.C. code. However, livestock, feeding and breeding; fruit, tree, nut, and vegetable farming; and forestry were also identified as preferentially taxed industries, enjoying tax benefits similar to those in the motion picture production and distribution industry.

In summary, the theory outlined above implies that the amount of investment in agricultural tax shelters will be positively related to the marginal tax rate. Of course, empirical analysis must be undertaken to determine the magnitude of the effect of taxation on farm tax shelter investment.

Tax Return Data on Farming Activity

In this paper the use of farming for tax avoidance purposes is empirically investigated with tax return data. Statistics on farm income (or loss) reported on Schedule F of the Federal 1040 individual income tax return have been published for the years 1963 to 1986 (see table 1). During this period the number of personal tax returns reporting farming activity fell by 21%, which is consistent with the general movement of resources out of agriculture in the United States. Personal farm income in aggregate has been on a downward trend since 1973 (especially in real terms) that culminated in negative incomes (net farm losses) throughout the 1980s. In 1963 there were about one-half as many Schedule Fs reporting losses as there were showing farm profits. By 1974 the loss/profit ratio based on the number of tax returns had risen above unity, and it continued to move upward, peaking at a value of 2.11 in 1984. A similar trend can be noted by comparing the dollar amounts of farm profits and farm losses. In 1963 farm losses were only 40% as large as farm profits. In 1984 farm losses reported on Schedule Fs were over three times as great as farm profits. Some recovery in terms of farming profitability has occurred since the record loss year of 1984.

During the time period covered by table 1, the marginal federal tax rate facing many individuals exhibited an upward trend that was halted only by declining inflation rates and the statutory tax rate reductions enacted in 1981. State income tax rates also rose over much of the 1963–86 period. Consequently, these patterns of farming tax losses and individual income tax rates are consistent with the view that rising tax rates encourage agricultural investment intended to produce tax savings rather than food and fiber.

The approach followed here to test the impact of tax rates on farm tax shelter activity is to examine the amount of farm profit or loss reported by individual taxpayers in the same year. A cross-sectional comparison removes the influence on farm losses of factors such as general business conditions and tax rules, which change over time. A rich source of microlevel data on farm income is the Internal Revenue Service's *1983 Individual Tax Model File,* a stratified random sample of individual income tax returns.[3] Table 2 shows the incidence of farm profits and losses and the amount of net farm income reported on 1983 tax returns. Overall a Schedule F was included on about 2.7 million returns (see table 1), or 2.81% of the 96.3 million total individual tax returns filed for 1983. The number of Schedule F returns indicating a farm loss was 1.81 times as great as the number reporting profit from farming. The average net income from farming activity (based on all returns) was a loss of $96, whereas the average Schedule F reported a loss of $3,416. The total net income reported on Schedule F in 1983 was $−9.3 billion (see table 1).

This aggregate picture conceals substantial variation by income level in the incidence and value of farm net income. Specifically, the percentage of tax returns reporting a Schedule F loss rises dramatically as nonfarm income increases, from 1.32% in the under $25,000 category to over 12% in the top income groups. Among taxpayers whose net income from wages, salaries, capital, and other nonfarm sources exceeded $100,000 in 1983, net losses from farming were six times as likely as net profits. The skewed distribution of farm losses by nonfarm income has also been noted by Woods.

When filed by an individual taxpayer with very little income from nonfarm sources, a Schedule F is more likely to identify a true farmer than a tax farmer. In 1983 about 61% of all tax returns reporting farm activity came from the lowest nonfarm income category in table 2 and the av-

[3] The *1983 Individual Tax Model File* consists of a sample of actual personal income tax returns (forms 1040, 1040A, and 1040EZ) filed by U.S. citizens and residents. This data base is prepared by the Internal Revenue Service to simulate the administrative and revenue impacts of tax law changes and to provide statistical tabulations relating to the incomes and taxes paid by individuals. Additional details of these data are provided in Strudler and Jamerson.

Table 2. Percentages of Individual Tax Returns Reporting Schedule F and Mean Net Farm Income in 1983

Return Category	Number of Returns (1,000)	Percent Reporting Schedule F Loss	Percent Reporting Schedule F Profit	Mean Net Farm Income ($) All Returns	Mean Net Farm Income ($) Schedule F Returns Only
All returns	96,322	1.81	1.00	−96	−3,416
Returns with nonfarm income ($1,000) equal to:					
Under 25	66,532	1.32	1.17	−5	−201
25–50	23,422	2.61	0.60	−164	−5,109
50–100	5,414	3.37	0.76	−298	−7,215
100–200	736	6.39	0.97	−1,932	−26,250
200–500	180	9.14	1.37	−6,355	−60,466
500–1,000	27	12.40	2.09	−15,345	−105,901
over 1,000	11	12.77	1.85	−45,026	−307,975

Source: U.S. Department of Treasury, *1983 Individual Tax Model File*. Data have been weighted to reflect the actual taxpaying population.

erage farm profit per farm return was $\$-201$. Such low returns are probably more indicative of the economic problems that faced farmers (especially small ones) in 1983 than agricultural investment for tax avoidance purposes. Tax return losses from farming activity grow rapidly as nonfarm income rises and reach very high levels in the highest income groupings. For example, taxpayers in the one-half to one million dollar nonfarm income category who filed a Schedule F reported an average net loss of about $106,000 in 1983, and those with one million or more nonfarm income reported an average farm loss of $308,000.

It is difficult to exclude tax shelter motives as an explanation for this pattern of increasingly negative farm income as other income rises.[4] True economic losses are disadvantageous to low and high income persons alike. Accounting, or paper, losses are more beneficial to wealthy individuals because they generate relatively larger tax savings under the progressive federal income tax. Thus, the pattern of farming activity revealed in table 2 is consistent with the hypothesis that higher tax rates increase the demand for farm tax shelters. Farm tax losses might rise with income for other reasons as well, however. Higher-income taxpayers have greater access to credit, tend to be better informed about tax shelter investments, and may be less risk averse than lower-income persons. Or perhaps, as Woods joked, the rich are "lousier" farmers than the poor. In any case, a multivariate statistical analysis is required to isolate the tax rate effect from the impact of income on tax-loss farming investment.

Econometric Analyses of Farm Tax Losses

In this section a reduced-form model of farm losses reported by individual taxpayers is described and estimated on a subset of returns from the *1983 Individual Tax Model File*. Two measures of farm tax shelter investment are constructed to serve as dependent variables in the empirical testing: (1) the incidence of farm losses (*INCIDENCE*), which is measured by a binary variable equal to 1 if a taxpayer files a Schedule F reporting a net loss and 0 otherwise; and (2) the dollar amount of farm losses (*LOSSES*), a continuous variable equal to the absolute value of negative farm income. The equations estimated take the general forms:

$$(1) \qquad INCIDENCE = f(MTR, INCOME, MARRIED, AGE65, DEPS, PCTFARM),$$
$$(2) \qquad LOSSES = g(MTR, INCOME, MARRIED, AGE65, DEPS),$$

where the independent variables are defined below.

According to the theory of portfolio choice, the primary independent variable is the prein-

[4] This pattern does not result because the data analyzed happen to come from a year in which overall farm income was negative. Replicating table 2 using data for 1979, a profitable year for farming (see table 1), yields comparable results.

vestment marginal tax rate (*MTR*), which in this paper is the statutory tax rate which applies when income is measured as actual taxable income minus net farm income. Under this definition, the taxable income for measuring *MTR* exceeds the reported taxable income of individuals who report a net loss from farming activity. *MTR* thus measures the rate of tax savings generated by the first dollar of negative farm income. Using this so-called "first dollar," or preinvestment, tax rate minimizes the simultaneity problem that results when the marginal tax rate is based on actual taxable income (Feldstein).

Two measures of *MTR* are used in the empirical estimation. *MTR*1 applies when preinvestment income equals actual taxable income minus net farm income reported on Schedule F.[5] This approach does not accurately measure the tax savings associated with farming investment if some farm income is reported as a capital gain rather than farm profit. Investment in breeding and dairy livestock, for example, generates deductions that reduce farm profit or increase farm losses; but the sale of these livestock produces income ultimately reported as capital gains with no impact on Schedule F net income. Accounting for the farm loss without also deducting the resulting capital gain income would overstate the preinvestment marginal tax rate (*MTR*1).

Unfortunately, the *Tax Model File* does not identify the precise source of capital gains and losses except to separate gains or losses from sales of stocks, bonds, a principal residence, and so forth (reported on Schedule D) from those resulting from sales or exchanges of assets used in a trade or business (reported on Form 4797). However, a second marginal tax rate (*MTR*2) can be computed by assuming that for taxpayers filing a Schedule F all of the taxable income reported on Form 4797 is associated with the farm investment.[6]

These two marginal tax rate variables incorporate both federal and state income tax structures. The federal tax rate assigned each taxpayer was based on the 1983 rate schedule (U.S. Department of Treasury 1986) and incorporated the minimum tax provision. The state tax rate equaled that which would be applied if nonfarm income were reduced by the standard deduction amount and allowances for personal exemptions. Details of state income tax structures are summarized in Advisory Commission on Intergovernmental Relations. *MTR* equals $f + s - fs$ for itemizers and $f + s$ for taxpayers claiming the standard deduction on their federal returns, where f and s are the applicable federal and state marginal rates. When federal income taxes can be deducted on state returns, the combined tax rate equals $(f + s - 2fs)/(1 - fs)$.

The use of state tax rates provides an independent source of *MTR* variation (apart from that caused by income differences) that is helpful in isolating the pure tax-rate effect on farming activity. State marginal tax rates range from zero to the teens, so there is substantial variation in the combined federal and state *MTR* even among taxpayers having the same income level. For example, a married taxpayer whose taxable income from nonfarm sources equalled $110,000 would have faced a 50% *MTR* in 1983 if he resided in Texas or Florida (states with no personal income tax), whereas a similar individual living in New York would have confronted a 57% *MTR* (assuming deductions were itemized). Theory suggests that the latter individual would have more incentive to invest in farming (or other assets) as a tax shelter.

Because confidentiality rules prohibit the identification of state of residence on certain returns in the *Tax Model File*, for estimation purposes our sample excludes taxpayers having adjusted gross income (AGI) under −$200,000 or over $200,000. Taxpayers in the income levels included in our sample filed over 99% of the farm (Schedule F) tax returns received for 1983. Of the 25,369 farm returns (out of 2.71 million total) which do not identify state of residence, 20,232 reported a net loss from farming and 5,137 reported a net profit. These returns excluded because of confidentiality restrictions generated 12.4% of all net farm losses in 1983 but only 3.9% of farm profits. Therefore, the sample used for estimation is biased by the omission of very high (or low) income taxpayers who report substantially above-average net farm losses. Consequently, the estimated coefficient of *MTR* in the equations presented below is likely to understate the true impact of the marginal tax rate on farm tax losses. Two additional criteria were used for sample selection purposes. First, to remove possible bias caused by fluctuating incomes and to simplify measurement of the marginal tax rate, tax returns using income averaging were deleted. Second, taxpayers with negative nonfarm income were eliminated from the sample.

[5] Operationally, the amount reported on line 37 of the 1983 Form 1040 minus the amount on line 19.

[6] For the taxpayer reporting Schedule F income or loss, preinvestment taxable income equals line 37 (Form 1040) minus line 19 (Form 1040) minus line 15 (Form 1040) minus 40% of line 16 (Schedule D).

To control for the anticipated positive effect of income on tax shelter investments in agriculture, the amount of nonfarm disposable income (*INCOME*) is also included as an independent variable. *INCOME* equals nonfarm income minus the income tax liability that would have been due if farm income were zero. Because previous empirical studies have often found that demographic variables are related to taxpayer behavior, the farm loss equations also include the number of taxpayer dependents (*DEPS*) and dummy variables to identify taxpayers who are age 65 or older (*AGE*65) and who are married (*MARRIED*).[7] The expected impacts of these variables on farm tax losses are unclear, although elderly taxpayers may be less inclined to undertake investments that shift taxable income into the future. The final independent variable is the percentage of all tax returns in the taxpayer's state of residence which report any farming activity on Schedule F (*PCTFARM*). This variable is included to control for the effects on farming activity of climate, natural resources, and other variables that differ by state and that might otherwise be captured by the estimated coefficient of *MTR*.

[7] For instance, Clotfelter and Steuerle found that marriage and the presence of dependents raise charitable contributions. Long and Gwartney found that aggregate tax losses are relatively lower for elderly taxpayers and, in certain income ranges, are higher for married couples.

Table 3 presents the estimated determinants of the incidence of farm tax losses. Because the dependent variable is dichotomous, the equations were estimated using logit analysis. Equation (1) reveals that the probability that a loss from farming activity is reported on an individual tax return is positively related to the marginal tax rate, which in this case directly reflects the tax savings generated by the farm loss. Technically, the coefficients (β's) in table 3 describe the impact on the natural logarithm of the odds that a farm loss is reported, not the actual probability of reporting a farm loss. To determine the marginal impact of *MTR*1 on the probability (P) that a farm loss is reported, the formula $\Delta P/\Delta MTR1 = \beta_{MTR1} \cdot P \cdot (1 - P)$ was utilized, as explained in Pindyck and Rubinfeld. The *MTR*1 coefficient in equation (1) yields an elasticity of the incidence of farm losses with respect to the tax rate of 0.53. This estimate implies that a 25% cut in marginal tax rates (similar to that of the 1981 tax act) in the long run would reduce the overall incidence of Schedule F losses from 1.81% of tax returns (see table 2) to 1.57%, other things constant.

The incidence of farm losses also varies directly with the level of disposable nonfarm in-

Table 3. Logit Analysis of the Incidence of Farm Losses Reported on Individual Tax Returns in 1983

Explanatory Variable	All Levels of Nonfarm Income[a] (1)	(2)	Nonfarm Income Greater than \$100,000[a] (3)	(4)
*MTR*1	.0197		.0799	
	(8.36)		(9.43)	
*MTR*2		.0182		.0825
		(7.79)		(9.27)
INCOME	.0131	.0123	.0167	.0146
(\$1,000)	(21.77)	(20.32)	(18.38)	(16.61)
MARRIED	.9684	1.0151	.3951	.4966
	(11.61)	(12.04)	(2.90)	(3.50)
*AGE*65	.1203	.1354	−.1963	−.1751
	(1.47)	(1.66)	(−1.48)	(−1.32)
DEPS	.0292	.0287	.0209	.0173
	(1.51)	(1.47)	(.71)	(.57)
PCTFARM	.1795	.1717	.2015	.2032
	(27.37)	(26.94)	(16.34)	(16.40)
Intercept	−6.2307	−6.1723	−9.1230	−9.1437
	(−60.92)	(−60.70)	(−18.65)	(−17.97)
Chi-square	2,507[b]	2,334[b]	919[b]	803[b]
N	62,648	62,602	8,581	8,531

Note. Asymptotic t-statistics in parentheses.
[a] Subject to the criteria listed in the text.
[b] Indicates that the equation is statistically significant at the .01 level.

come. Married taxpayers are significantly more likely to report a tax loss from farming than other persons, but other demographic variables reflecting elderly status and family size are not statistically related to the incidence of farm losses. The positive coefficient of *PCTFARM* confirms that the greater the amount of farming activity in a state, the higher the incidence of Schedule F losses among taxpayers residing in the state, all else constant.

Equation (2) shows that the signs and magnitudes of the logit coefficients are basically unchanged when a broader concept of the income associated with the farm investment is used in the measurement of *MTR*2 and *INCOME*.[8] However, several of the estimated parameters change significantly (regardless of how the marginal tax rate and income variables are measured) when the logit model is estimated using just those taxpayers having nonfarm income above $100,000. In particular, equations (3) and (4) show that the *MTR* coefficients increase roughly fourfold, yielding a tax rate elasticity of the incidence of farm losses of approximately 3.5. This finding is consistent with a recent analysis of income tax avoidance by Long and Gwartney. Using 1979 tax return data, they found that the impact of higher tax rates on tax loss investments was substantially larger among individuals with preinvestment incomes above $80,000 (which corresponds to about $100,000 in 1983 dollars) than among lower-income taxpayers.

The level of nonfarm disposable income also has a relatively larger positive effect on farm loss incidence in the upper-income sample, whereas marital status exerts a much smaller impact on the incidence of a Schedule F loss. The latter finding is not at all surprising—"genuine" farmers are statistically more likely to be married than nonfarmers, and the high-income taxpayer sample excludes most real farmers. The *AGE*65 coefficient reverses sign in equations (3) and (4), but neither it nor the coefficient of *DEPS* is statistically different from zero. The control variable *PCTFARM* retains its positive sign and high significance level in the farm loss incidence equations for the high-income sample.

Table 4 presents the estimated determinants of the dollar amount of farm losses on individual returns that reported a Schedule F loss in 1983. The *Tax Model File* sampling weights were applied to the data to make the size of farm tax losses reported on sample returns representative of the parent population. Given the evidence in table 3 and elsewhere that upper-income indi-

[8] The fact that a different measure of nonfarm income was used to compute *MTR*2 explains the small difference in sample sizes between the even- and odd-numbered equations.

Table 4. Regression Analysis of the Dollar Amount of Farm Losses on Individual Tax Returns Reporting Schedule F Loss in 1983

Explanatory Variable	Nonfarm Income Less than $100,000[a]		Nonfarm Income Greater than $100,000[a]	
	(1)	(2)	(3)	(4)
*MTR*1	622		4,743	
	(18.50)		(8.18)	
*MTR*2		544		5,729
		(15.72)		(7.95)
INCOME ($1,000)	−336	−309	1,116	1,071
	(−12.72)	(−10.99)	(16.29)	(14.43)
MARRIED	2,945	2,808	11,128	14,014
	(4.41)	(4.05)	(1.13)	(1.33)
*AGE*65	−809	−958	−7,746	−11,136
	(−1.18)	(−1.34)	(−.92)	(−1.26)
DEPS	548	549	−3,385	−5,201
	(2.98)	(2.86)	(−1.58)	(−2.30)
Intercept	−4,963	−3,235	−293,703	−338,966
	(−5.81)	(−3.74)	(−9.15)	(−8.61)
R^2	.5312	.4932	.4704	
F	195[b]	168[b]	123[b]	105[b]
N	1,038	1,041	835	791

Notes: *t*-statistics in parentheses. Equations are weighted.
[a] Subject to the criteria listed in the text.
[b] Indicates that the equation is statistically significant at the .01 level.

viduals engage in more tax avoidance when tax rates rise than lower-income persons, the regression model was estimated separately for two income groupings. Equations (1) and (2) reveal that when nonfarm income is less than $100,000, a unit increase in the marginal tax rate raises farm losses by about $500 to $600. In contrast, among taxpayers with nonfarm incomes over $100,000, a one percentage point increase in the marginal tax rate raises farm losses by either $4,743 or $5,729, depending on how *MTR* is measured. The elasticity of farm losses with respect to the marginal tax rate equals 2.49, 2.13, 4.22, and 5.17 in equations (1), (2), (3), and (4), respectively. Given that the coefficients of *MTR*1 and *MTR*2 are all statistically significant at the one percent level or better, the pattern of these tax rate effects suggests that usage of farming investments for tax-avoidance purposes does in fact rise with income.

According to equations (1) and (2), the level of nonfarm disposable income is negatively related to farm losses when income is less than $100,000. However, when nonfarm income exceeds this amount, farm tax losses expand with income. Actually, the first of these two conclusions is somewhat misleading. When the regression model was reestimated with the squared value of *INCOME* added, the results (not reported) indicated that the negative relationship between farm losses and income disappears once nonfarm income reaches about $54,000. This phenomenon may reflect the presence in the sample of genuine farmers who recorded true economic losses in 1983. It may also indicate that farm investments are income-inferior tax shelters for all but high income taxpayers. In any case, the finding that farm losses and *INCOME* are positively related (unless nonfarm income is relatively low) is consistent with the variation in net farm returns by income level illustrated in table 2.

When taxpayers with nonfarm income under $100,000 report a Schedule F loss, two of the demographic variables (*MARRIED* and *DEPS*) are positively and significantly related to the size of the tax loss. In contrast, farm losses are not consistently related to taxpayer characteristics such as age or marital status in the over-$100,000 sample. This finding lends additional support to the view that farm losses reported on high-income returns are the result of deliberate tax shelter investments in agriculture. If such investments were not primarily motivated by tax considerations, then one might expect some relationship between farm losses and noneconomic variables, as in the case of the impact of marital status and family size on investment in owner-occupied housing (Silberman, Yochum, and Ihlanfeldt).

In summary, the *MTR* coefficients in tables 3 and 4 are consistently positive and highly significant, suggesting that higher tax rates increase the incidence and amount of farm losses reported by individual taxpayers. While the use of agricultural investments for tax avoidance purposes has long been thought to occur, empirical evidence isolating the tax rate effect on farm losses has generally been lacking. The methodology employed to identify the tax rate effect involved a statistical comparison of taxpayers facing different marginal rates but operating under basically the same rules regarding the measurement of taxable income and tax liability. Consequently, the estimated marginal tax rate coefficients could be used to project the decline in farming tax-shelter activity accompanying a statutory reduction in tax rates, *ceteris paribus*. However, such projections would surely understate the anticipated decline in agricultural tax shelters following the 1986 Tax Reform Act because this legislation also contained numerous other provisions likely to deter tax-avoidance investment.

Concluding Comments

In this paper a variety of empirical evidence has been presented to suggest that an increase in personal income tax rates will induce individuals, especially high-income ones, to farm the tax code in order to shelter income from taxation. Consequently, recent federal tax rate reductions can be expected to reduce farm investments intended to produce tax losses rather than agricultural output. The conclusion that some income losses associated with farming activity are the byproduct of deliberate tax-avoidance investments in agriculture is not incompatible with the fact that many American farmers have confronted genuine financial hardships in the 1980s. Much agricultural investment is undertaken with the expectation of increasing income flows or capital appreciation, using tax advantages such as rapid depreciation and investment tax credits to help achieve these goals. Tax considerations are not the sole source of low aggregate farm incomes during recent years. However, recognition that some agricultural investment is tax motivated implies than an aggregate measure of the net income from farming is a misleading in-

dicator of true farming profitability because it conceals the tendency of farm losses to increase with investors' income levels.

The extent to which taxpayers utilize farming investments as tax shelters and the amount of nonfarm income avoiding taxation as a result may not be judged all that significant when compared to tax avoidance in aggregate or to other specific avoidance techniques such as real estate investment.[9] However, tax-loss farming may create some troubling side effects, such as bidding up the prices of farmland and other resources and subjecting genuine farm operators to competition with investors who consider farm profit in the economic sense as unnecessary for their purposes (Woods). Furthermore, farm tax shelters constitute yet another channel through which the personal income tax base is eroded by high marginal tax rates. Tax-loss farming illustrates the ingenuity and willingness of individuals to arrange their economic activities in order to minimize the tax burden. Consequently, tax policies designed to reduce high marginal tax rates are desirable from the standpoint of alleviating the resource misallocations and distributional inequities associated with agricultural and other tax shelters.

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[9] For example, using a tobit analysis of aggregate income tax losses in 1979, Long and Gwartney estimated that among upper-income individuals a unit increase in the marginal tax rate raises losses by anywhere from $1,800 to $4,400. The determinants of farm tax losses have also been estimated with tobit analysis rather than with the two-step procedure that was reported in this paper. Both procedures imply that farm losses rise by no more than $400 with each percentage point increase in the tax rate.

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Temporal Analysis of Income Earned by Former Agriculture Students

Warren P. Preston, Josef M. Broder, and Maria Cristina P. Almero

Earnings profiles of students formerly enrolled in a college of agriculture were analyzed in the context of labor market information. Analysis of covariance was used to estimate models explaining how salary determinants changed during the alumni's careers. Gender, education, year of job market entry, profit sharing, and personal emphasis on earnings were found to be significant determinants of starting incomes. Starting incomes were found to be a prime determinant of later year salaries along with experience on the immediate job, profit sharing, oral and technical skills, marital status, and place of residence. Labor market information was found to vary in quality across participants and have a limited shelf life.

Key words: careers, college of agriculture, compensation, human capital, job skills, labor market.

Conditions of imperfect competition characterize virtually all labor markets. Numbers of sellers (workers) or buyers (employers) often are small, especially for higher level positions. The goods offered for exchange are not homogenous because each potential employee offers a unique portfolio of abilities and skills. Market entry and exit are neither costless nor instantaneous. According to the Employment Management Association, companies spent an average of $5,856 to hire a professional or managerial employee during 1987 (*Wall Street Journal*). Relocation costs for employees also are substantial. Finally, information available in labor markets is far from perfect. Workers and employers possess different information sets that can be revealed selectively in the labor market. The result is an asymmetry of information among labor market participants.

Because of uncertainty, information regarding labor market conditions is of variable quality and is subject to differing interpretations. In particular, the market for graduates from colleges of agriculture illustrates differences in the assessment of available labor market information. Enrollments in both undergraduate and graduate agricultural programs have declined steadily over the past ten years (Suter). Undergraduate enrollments alone dropped by as much as 24% from 1980 to 1987. Such trends suggest that the market responded to perceptions of declining career opportunities in the agricultural sector. On the other hand, the same trends have led some observers to predict labor shortages of individuals with master's and doctoral degrees in high-technology disciplines within colleges of agriculture over the next ten to fifteen years (Coulter, Stanton, and Goecker). Surpluses or shortages of qualified individuals should not exist in perfectly functioning labor markets.

Information plays a critical role in the operation of labor markets. From an individual worker's perspective, labor market information evolves in step with stages of the worker's career. For example, newcomers to the labor force may be unknowledgeable about labor market conditions and their own capabilities. A search process among jobs may be necessary before individuals become established in an appropriate career track. At different stages of the career, the relative importance of various factors that influence salaries may change. Thus, there is a

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need to learn which factors are important in determining individuals' salaries and how these factors change over workers' careers.

The literature on labor markets for agricultural college alumni is limited. These studies have focused on curricula (Sjo, Orazem, and Biere; Kropp); on student characteristics, goals, and perceptions (Dunkelberger et al., Schrimper); on monetary returns (Broder and Deprey); on training (Roberts and Lee); and on markets for graduates (Schneider). A common feature of these studies is that each deals with only a single point of time. In particular, there is a lack of information about the relationship of individual characteristics to salary earned both on leaving college and after several years of labor market experience.

An analysis of the factors that contribute to the earnings of alumni would provide valuable information for potential employees, employers, and individuals responsible for student recruitment, curriculum design, and educational reform. Moreover, an examination of how income determinants may change over the course of a career would provide for even richer implications. Suitable recommendations for career advancement, for example, would be directly affected if income determinants vary with career maturation. The design of undergraduate and graduate programs in agriculture also is affected by the timing of payoffs to human capital investments. Curricular reform efforts aimed at increasing student enrollments may fail unless monetary returns to graduates are realized early in the career.

The purpose of this study is to determine the extent to which individual characteristics, educational backgrounds, and occupational experiences influence the earnings of former agriculture students over time. The study extends earlier research efforts by explaining entry level incomes of former students as well as later incomes, when some job experience has been gained. Of particular interest are changes in labor market information that occur as individuals gain work experience.

Respondent Characteristics

Data for the study were obtained from the S-200 research project ("Occupational Career Paths of Former Students in Southern Land Grant Universities") conducted jointly by southern land grant universities and the Cooperative State Research Service of U.S. Department of Agriculture (USDA). The S-200 project was begun in 1984 and followed up the S-114 project ("Defining and Achieving Life Goals: A Process of Human Resource Development") conducted during the late 1970s (Dunkelberger et al.).

Data for the S-200 project were obtained through a mailed questionnaire administered to a random sample of undergraduate students who were enrolled in agricultural programs during 1977. The mailed survey included questions on educational attainment, career mobility, college curriculum competencies and skills, opinions about agricultural careers, and other personal characteristics. A total of 296 former students from the College of Agriculture and Life Sciences at Virginia Polytechnic Institute and State University (Virginia Tech) received questionnaires as part of the S-200 project. The analysis presented in this paper is based on 243 usable responses. Although limited to one school, the sample is presumed to serve as a reasonable representation of the general population of agriculture students from land grant universities.

Educational Characteristics

Because the initial sample was drawn from students in various stages of their undergraduate programs, some of the respondents had changed majors before graduation. Thus, the survey included respondents who later earned nonagricultural degrees. Eighty percent of the respondents graduated from agriculture, 15% graduated from other colleges, and 5% did not graduate. Greater numbers of agriculture college students were in forestry (28.0%), followed by animal science (19.3%) and horticulture (7.8%). Students who switched to nonagriculture majors were in a variety of fields but with larger representation in business (2.9%), biological science (2.1%), and education (1.6%).

Educational attainment patterns show that 51% of the respondents terminated formal education with bachelor's degrees. Another 16% earned master's degrees, and about the same percentage completed other additional education beyond a bachelor's (such as M.B.A.s or technical programs). About 3.7% of the respondents earned professional degrees, such as M.D. or D.V.M. At the time of the survey, about 6% of the respondents were enrolled in master's programs, 3.7% in professional degree programs, and 2.5% in doctoral programs.

Labor Market Characteristics

Less than half of the respondents (40%) identified their first full-time jobs following college as having duties related to agriculture. This proportion remained nearly constant as respondents acquired labor market experience. By 1987, 39% of the respondents held jobs that they perceived as involving agriculture. Respondents earned an average starting annual salary of $16,926 (adjusted to 1985 dollars using the consumer price index) on the first job after college. Over three-fourths of the respondents earned under $20,000 on their first jobs. By 1985, respondent incomes averaged $24,160.[1] Fewer than one-third of the respondents reported 1985 personal income under $20,000.

Models of Earned Income

A central focus of this study was to determine how the importance of the various determinants of personal income may change during different stages of one's career. Given the expectation that the relative influence of income determinants would change over time, two separate models of personal earnings were developed. The first model attempted to explain income earned at the beginning of the respondents' careers. During the formative period of career development, little concrete information about job performance would be available. Employer's assessments of a prospective employee would tend to rely on indirect measures of career potential, such as performance in college and personal background.

Starting salaries were entered into the first model as the annual pretax salary earned on the first job after leaving college (hereafter, simply "starting income" or *INC*1). Starting annual salaries were converted to constant 1985 dollars to adjust for the effects of inflation over time because individuals started their first full-time jobs in different years. Excluded from the analysis were respondents who failed to respond to the question, for whom the question was not applicable, or who reported zero income.[2] Starting salary model estimates were based on 205 usable observations.

The second model attempted to explain respondents' earnings after several years of job experience. Work experience provides additional information to both sides of the labor market. Employers gain direct insights into employee job performance, while employees reassess job expectations and career potentials.

Respondent incomes were entered into the second model as the annual pretax income reported for 1985 (hereafter referred to as "1985 income" or *INC*2). Excluded from the analysis were those for whom the question was not applicable, those who did not respond, and those who started their most recent jobs after 1985. The 1985 income model estimates were based on 182 observations, 23 less than the starting income model. Sample differences were attributed to random events and thus were assumed not to be a potential source of systematic bias in model estimates.

With few exceptions, similar explanatory variables were selected for each model. An individual's potential earned income was hypothesized to be influenced by investments in human capital, which include formal education and labor market participation and training. Earnings might also be affected by labor market imperfections that enhance or impede labor resource mobility, such as job location, and personal characteristics including gender, age, and marital status.

Analysis of covariance (ANCOVA) estimates for both models were obtained using the SAS general linear models procedure (SAS Institute). ANCOVA is mathematically equivalent to ordinary least squares (OLS) regression with both continuous and appropriately defined dummy variables. Lacking sufficient theoretical or empirical evidence for alternative specifications, the models were specified as linear functional forms.

Starting Income Model Results

ANCOVA results for the estimated starting income model are given in table 1. The coefficient of determination (R^2) for the model is 0.29, and the overall model is significant at the 0.01 level. To examine for possible multicollinearity, a cross-correlation matrix for all explanatory variables was obtained. The resulting correlation coefficients were all less than 0.3, which is considered evidence of little if any correlation (Hinkle,

[1] Unlike the question regarding starting income, which was open ended, the question regarding 1985 gross personal income was posed as categorical choices to enhance response rates. Hence, the midpoint of each category was used to best approximate each income bracket for the 1985 data.

[2] Consideration was given to constructing a suitable framework for incorporating responses from those reporting no income. However, the number of such observations was too small to provide statistically meaningful results.

Table 1. Analysis of Covariance and Parameter Estimates for Starting Income, in 1985 Dollars

Source of Variation	df	F-value	R^2
Regression	17	4.57	0.29
Error	187		
Total	204		

Variable	df	F-value	Level	Estimate
INTERCEPT	1	12.89***[a]		$62,984
JOBYEAR	1	6.18***		−544
*EDUC*1	2	3.41***	B.S. or less	0
			Enrolled advanced degree	−523
			Completed advanced degree	3,102
MAJOR	2	0.77	Agricultural (non-forestry)	0
			Agricultural (forestry)	−605
			Nonagricultural	609
*SOUTH*1	1	0.87	South	0
			Non-South	784
PLCMT	3	1.14	University service	0
			Individual effort	−585
			Personal network	−646
			Private service	2,936
*AGJOB*1	2	1.79	Farming	0
			Agribusiness	2,054
			Not farming or agribusiness	1,977
PAY	1	15.96***	Not/Somewhat important	0
			Important/Very important	2,928
*PRFT*1	1	6.28***	Not provided	0
			Provided	2,291
*HSG*1	1	1.49	Not provided	0
			Provided	−1,315
GENDER	1	6.10***	Female	0
			Male	1,733
ORAL	1	0.25	Not/Somewhat needed	0
			Much needed/Essential	556
TECHNICAL	1	0.01	Not/Somewhat needed	0
			Much needed/Essential	65

Source: S-200 Project survey of former Virginia Tech students.
[a] Single asterisk indicates statistically significant at the .10 level; double asterisk indicates statistically significant at the .05 level; triple asterisk indicates statistically significant at the .01 level.

Wiersma, and Jurs). The expectations, specifications, and findings of individual explanatory variables are discussed below.

The year that respondents began their first jobs after college (*JOBYEAR*) was entered as a continuous variable, or covariate, in the starting income model. In light of common perceptions about declining career opportunities in agriculture during the past ten years, a negative coefficient on *JOBYEAR* was expected. The coefficient for the covariate *JOBYEAR* was negative and significantly different from zero. Thus, respondents who began their first job in later years received lower real starting salaries than those who began earlier. The lower earnings of those who began later likely reflect labor market adjustments in response to depressed economic conditions, higher interest rates, and other market forces. That is, later wage rates may reflect market clearing levels at lower prices for a given value of marginal product.

The educational attainment of the respondent when beginning the first full-time job (*EDUC*1) was entered as a class variable with three levels: "Bachelor's or Less," "Enrolled in Advanced Degree," and "Completed Advanced Degree" (includes master's, professional degree, or doctorate). The level of educational attainment was expected to have a positive impact on starting annual salary, with those possessing higher educational levels earning higher salaries (Chiswick). *EDUC*1 was significant as shown by the F-value calculated for Type III or partial sum of squares (SAS Institute).

Given that educational attainment accounted for differing levels of income earned by the re-

Farming the Tax Code: The Impact of High Marginal Tax Rates on Agricultural Tax Shelters

James E. Long

Surprisingly little scholarly work has examined the practice of "farming the tax code," in which accounting losses on agricultural investments are used to shelter other income from taxation. Economic theory suggests that the amount of investment in agricultural tax shelters is positively related to the marginal tax rate. This hypothesis is empirically investigated using a sample of federal individual income tax returns filed for 1983. Both the probability of reporting a farm tax loss and the amount of farm losses are increased by a rise in the marginal tax rate, especially among upper income taxpayers.

Key words: agricultural investments, empirical analysis, tax rates.

The 1980s have been bleak years for American farmers. Their financial problems, resulting from high real interest rates, depressed prices and agricultural export sales, declining farmland values, and climatic difficulties, have been widely discussed. Data on farm incomes reported to the Internal Revenue Service substantiate these financial hardships. For example, individual taxpayers have reported aggregate net losses from schedule F (farm) activities in every year since 1980, with the cumulative total farm losses for 1980–86 exceeding $60 billion (see table 1).

Some portion of farm losses, especially those reported on individual tax returns, may not be the direct result of adverse business conditions in the farm sector. Because agriculture has long enjoyed preferential tax treatment, many individuals reporting farm losses may in fact be "farming the tax code" rather than the soil. Recent studies of taxpayer behavior have shed much light on the numerous ways in which individuals avoid taxation in the face of high marginal tax rates. These ways include tax evasion (Clotfelter 1983a), substituting fringe benefits for taxable compensation (Long and Scott, Woobury), consuming tax-deductible goods and services (Clotfelter 1983b, Long and Gwartney), deferring realized capital gains (Lindsey), and real estate partnership investments (Long and Gwartney).

Surprisingly, almost no scholarly work has reported the extent to which upper income taxpayers farm the tax code, although this practice has been widely acknowledged. Noting that income tax returns for 1966 and 1970 revealed that a large amount of farm losses were reported by taxpayers who had high nonfarm incomes, Woods suggested that either people were exploiting the tax code or the rich made "lousy" farmers. Davenport, Boehlje, and Martin expressed a similar view when they stated, "Were agriculture less tax favored than it is, . . . there would be fewer high-bracket taxpayers in farming" (p. 30).

The primary purpose of this paper is to investigate empirically the tax shelter motive for agricultural investments by individuals. In the next section, some of the major tax provisions affecting farming are briefly discussed, including those contained in the Tax Reform Act of 1986. A theoretical discussion of investment choices and preferential taxation then is presented. Individual tax return data pertinent to the tax shelter aspect of farming also are presented and the relationship between farm losses and the rate of taxation is analyzed econometrically.

Agricultural Tax Preferences—Before and After 1986

American agriculture has enjoyed a variety of general and specific income tax preferences since

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Table 1. Measures of Farming Activity Reported on Individual Income Tax Returns, 1963–86

Year	Number of Returns with Schedule F (1,000)	Net Farm Income or Loss on Schedule F ($1,000)	No. Returns with Farm Loss ÷ No. Returns with Profit	Amount of Farm Losses ÷ Amount of Farm Profits
1963	3,194	2,756,000	.515	.408
1964	3,110	2,636,000	.555	.439
1965	3,034	3,365,000	.518	.355
1966	3,009	4,070,266	.507	.320
1967	3,012	3,353,443	.596	.397
1968	3,033	3,127,491	.639	.435
1969	3,092	3,577,574	.596	.417
1970	3,026	2,788,713	.689	.510
1971	2,775	2,187,999	.869	.600
1972	2,791	4,106,393	.724	.440
1973	2,866	7,227,744	.740	.360
1974	2,804	4,996,198	1.047	.562
1975	2,755	3,563,325	1.056	.648
1976	2,819	3,455,781	1.101	.666
1977	2,487	504,256	1.120	.939
1978	2,705	3,565,293	1.051	.677
1979	2,605	2,123,614	1.094	.808
1980	2,608	−1,792,466	1.322	1.180
1981	2,641	−7,811,958	1.684	1.916
1982	2,689	−9,833,548	1.882	2.230
1983	2,710	−9,294,485	1.800	2.103
1984	2,694	−13,095,506	2.111	3.066
1985	2,621	−12,005,483	1.940	2.849
1986	2,533	−6,907,476	na[a]	1.768

Source: *Individual Income Tax Returns*, annual (1963 to 1985); Kalish and Shiley.
[a] na, not available.

1915. A detailed description of these preferences can be found in numerous government and academic publications dealing with farm taxation; for example, see Niles, Woods, Sisson, Moore, Krause and Shapiro, and Carman. The most important tax advantages have included (*a*) the option to use cash accounting, which requires no inventory records and allows input expenses to be deducted in the year actually paid even if they produce no income in that year; (*b*) tax regulations that permit farm assets such as livestock, real estate, and timber to qualify for long-term capital gains taxation; (*c*) accelerated depreciation of animals held for breeding purposes, single-purpose livestock structures, plants and trees, and certain other items; and (*d*) the ability to deduct the cost of developing certain capital assets, including the cost of raising dairy or breeding livestock and the cost of developing orchards and vineyards. Provision (*d*) has been particularly important in terms of enabling investors to convert ordinary income into long-term capital gains that, prior to the Tax Reform Act of 1986, were not fully taxed.

A different kind of tax benefit is that farming may provide an opportunity to participate in sporting or leisure activities such as horseback riding, hiking, hunting, and fishing. Someone once remarked that the best tax shelter is a business that permits an individual to deduct the cost of doing what he enjoys. Furthermore, there is no tax due on any nonpecuniary income or personal utility provided by farm assets, whether it be the pleasure obtained at a rural retreat or the excitement and prestige associated with breeding and racing thoroughbred horses. Recognizing that agricultural assets may pay off in different ways, Bullock suggested that much investment in U.S. agriculture is motivated toward "consuming" a rural way of life rather than generating a competitive rate of return.

The Internal Revenue Service has taken actions to prohibit some of the most flagrant tax avoidance schemes involving farming and other industries as well. In the case of the "hobby" farm, tax deductions are limited, and no farm losses can be used to offset other income if the IRS determines that the farm is not operated to make a profit (and the taxpayer cannot demonstrate an intention to make profits). Over the

spondents, the next step of analysis identified significant differences between the three levels of *EDUC*1. Parameter estimates for each level within the class variables are shown in the right-hand column of table 1. The reported coefficients correspond to coefficients that would have been obtained under OLS estimation with dummy variables. For *EDUC*1, "B.S. or Less" serves as the omitted dummy variable.

The least squares means procedure in SAS provided the complete difference of means tests for significant explanatory variables. A 0.10 level of significance was specified for all difference of means tests. Complete analysis of the significant variable *EDUC*1 entailed three paired comparisons among the three levels within *EDUC*1. Specifically, paired comparisons showed that those with advanced degrees earned significantly higher salaries than those with only a bachelor's and those enrolled in an advanced degree program. Salaries for those with bachelor's degrees or less and those enrolled in advanced degree programs did not differ significantly from each other. The significantly higher salaries earned by advanced degree recipients give further confirmation to the notion that more education leads to higher annual salaries.

Respondents' majors were entered as a categorical variable to account for possible variations in earnings attributable to the college major. There were three levels for the variable *MAJOR*: "Nonagricultural," "Agricultural (Non-Forestry)," and "Agricultural (Forestry)." School of Forestry majors were classified separately from other College of Agriculture majors to obtain more homogenous units with respect to training and possible career choices. Furthermore, because all of the respondents initially were enrolled in the College of Agriculture, results of the *MAJOR* variable would show whether transferring into other colleges affected later earnings. Parameter estimates pointed toward higher starting salaries for those who transferred to majors outside agriculture than for those who remained in agriculture. These differences, however, were not statistically significant.

The binary variable *SOUTH*1 identified whether the first job was located in one of thirteen southern states. Because wage rates in the South generally lag behind other regions, those who obtained jobs outside the South were expected to earn higher incomes (Broder and Deprey). The parameter estimate suggested higher salaries for individuals located outside the southern region. However, the computed F-value showed that *SOUTH*1 did not contribute significantly to explaining the variation in starting incomes, suggesting that job region was not an important determinant of starting salaries. This finding was attributed to Virginia's status as a regional transition state.

The contribution of job placement institutions (*PLCMT*) was entered as a categorical variable with four levels. The categories included "University Services," such as the placement office, dean's office, or faculty member; "Private Services," such as public or private employment agencies; "Individual Efforts," such as civil service application, employment advertisements, direct applications, military service, self-employment, or others; and "Personal Networks," such as contact of a relative or friend, or a return to a family business or farm. Human capital theory suggests that individuals maximize their economic welfare given the costs of their investments. The *PLCMT* variable was included to determine if "who you know" rather than "what you know" made a difference in salaries earned on the first job. Results showed that the path followed to find the first job did not make a significant difference in determining first job starting salaries. Although "knowing the right people" may have contributed to finding the first job, it made little apparent difference in the salary earned.

A binary variable (*AGJOB*1) indicated whether the respondent's job involved farming, agribusiness, or neither. The *AGJOB* variable was included to detect possible differences in starting salaries between those employed in farming and in the agricultural and nonagricultural sectors. Results suggested that the nature of the job was not an important determinant of starting salaries. With respect to earnings, then, the respondents fared the same in both the agricultural and nonagricultural sectors. Although not significantly different from zero, parameter estimates suggested that those engaged in farming received about $2,000 less in starting salaries than those not involved in farming.

Respondents' rankings of the importance of pay in their decisions to accept their first jobs was included as a class variable. The two levels for the *PAY* variable were "Not/Somewhat Important," and "Important/Very Important." *PAY* was used to determine how the perceived importance of monetary returns affected earnings and to account for nonmonetary factors in career choices. Because pay is an indicator of the return to investments in human capital, respondent perceptions of its importance were assumed to show the degree to which financial compen-

sation influenced the selection of initial employment. Higher earnings were expected for those considering pay as important or very important. Results showed that the variable *PAY* contributed significantly to explaining the variation in starting income. Parameter estimates indicated that those who rated *PAY* as important or very important earned mean starting salaries $2,928 higher than those who viewed *PAY* as not or somewhat important.

The fringe benefit profit sharing (*PRFT*1) was entered as a binary variable indicating whether the respondent participated in a profit-sharing plan. As added monetary compensation, profit-sharing benefits were expected to be a positive determinant of earnings. That is, the provision of profit-sharing benefits was hypothesized to be directly associated with earnings, with more provided at higher income levels. Respondents were assumed to have included their earnings from profit sharing in their reported incomes. *PRFT*1 was found to be significant. Respondents who were provided with profit sharing benefits earned mean starting incomes $2,291 higher than those without such benefits.

A binary variable (*HSG*1) was included to indicate the provision or nonprovision of housing benefits. As nonmonetary compensation, the provision of housing was expected to be inversely associated with earnings. Although parameter estimates suggested that respondents with housing benefits received lower mean starting salaries than respondents without housing benefits, the difference was not statistically significant.

Gender has been a significant factor in explaining variations in earnings, with males earning significantly higher average salaries than females (Ferber, Green, and Spaeth; Lewis and Emmert; Remus and Kelley; Broder and Deprey). *GENDER* was entered as a binary variable and was found to be significant in explaining the variation in starting income. Parameter estimates showed that starting salaries of males averaged $1,733 more than that of females. Results for the *GENDER* variable are consistent with the voluminous literature on the salary differential between the sexes. An explanation based on human capital arguments is that females may lack resource mobility because of personal interests and family, which greatly restricts their potential earnings. Combined with employer perceptions that women may be greater hiring risks because of possibly higher turnover rates, lower salaries can be interpreted as risk premiums for hiring females. Employers may pass some of these risk premiums on to female employees as lower salaries.

The starting income model included two variables related to retrospective opinions about the importance of skills and competencies gained in college to the respondents' own careers. The variables represented proxy measures of interpersonal skills (*ORAL*) and technical skills (*TECHNICAL*). The skills were classified as being either "Not/Somewhat Needed" or "Much Needed/Essential." Neither variable contributed significantly to explaining the variation in starting incomes.

1985 Income Model Results

The 1985 income model used continuous and categorical variables in an analysis of covariance. Gross personal income was used as the dependent variable. The analysis of covariance for the estimated model is given in table 2. The coefficient of determination for the model was 0.33.

Compared to labor market attributes applicable to the starting income model, more complete market information was available for the 1985 model. In particular, the survey respondents had acquired some job experience and a salary history by 1985. Job experience represents personal investment in human capital, especially for entry-level positions. Salary history provides additional conditioning information to both employers and workers themselves.

1985 earnings were expected to be sensitive to initial market assessments of employee potential as reflected by starting income. Starting income denotes the outcome of search processes conducted on both sides of the labor market. From the employee's perspective, acceptance of a job suggests that the expected costs (including opportunity costs) of continuing the job search exceed the expected benefits (in the form of greater monetary or nonmonetary returns). Likewise, the employer's decision to hire an individual suggests that the expected costs for continuing the search for a better candidate exceed the expected marginal benefits. Thus, starting income represents a mutual assessment of an individual's competitive position in the labor market and was expected to be a positive determinant of 1985 income.

Model results showed that starting incomes had a positive and significant impact on 1985 incomes. The description of the data showed that the respondent's real incomes in 1985 were larger

Table 2. Analysis of Covariance and Parameter Estimates for 1985 Income Model

Source of Variation	*df*	*F*-value	R^2
Regression	15	5.48	0.33
Error	166		
Total	181		

Variable	*df*	*F*-value	Level	Estimate
INTERCEPT	1	2.22		$7,324
*INC*1	1	19.50***[a]		0.563
*EXPER*1	1	1.28		466
*EXPER*2	1	5.55**		972
*EDUC*2	2	0.80	B.S. or less	0
			Enrolled advanced degree	−3,013
			Completed advanced degree	−744
MAJOR	2	0.60	Agricultural (non-forestry)	0
			Agricultural (forestry)	767
			Nonagricultural	2,141
*SOUTH*2	1	0.11	South	0
			Non-South	560
URBAN	1	6.54***	Non-urban	0
			Urban	3,332
*PRFT*2	1	3.45*	Not provided	0
			Provided	2,561
*HSG*2	1	0.35	Not provided	0
			Provided	−1,311
GENDER	1	0.72	Female	0
			Male	1,281
MARITAL	1	2.85*	Not married	0
			Married	2,421
ORAL	1	3.69*	Not/Somewhat needed	0
			Much needed/Essential	4,279
TECHNICAL	1	12.21***	Not/Somewhat needed	0
			Much needed/Essential	−5,386

Source: S-200 Project survey of former Virginia Tech students.
[a] Single asterisk indicates statistically significant at the .10 level; double asterisk indicates statistically significant at the .05 level; triple asterisk indicates statistically significant at the .01 level.

than their starting real incomes. However, the coefficient on starting income was less than one, indicating that later incomes were not the result of a simple linear growth of starting incomes. Other factors must have accounted for the real growth of individual's incomes.

The influence of starting income on 1985 income may be indicative of imperfections in labor market search processes. Salaries generally, and starting salaries particularly, are subject to random variation primarily because of imperfect information. For example, an adept bargainer may squeeze out a higher salary compared to a better qualified counterpart hampered by inferior negotiation skills. The results suggest that both random and systematic salary differences at the beginning of the career continue to influence salaries earned later in the career. The effect, however, dampens over time as shown by the coefficient of less than one on starting income.

The 1985 income model included two variables to account for human capital acquired by individuals through job experience. The sum of the variables (*EXPER*1 and *EXPER*2) equals the total number of years since a respondent began the first job. *EXPER*2 measures the length of employment on the most recent job held by a respondent; *EXPER*1 measures the length of all previous employment. The rationale for separating employment experience into two components was to capture differential effects of the information conveyed by each of the measures. It was hypothesized that the labor market emphasizes experience acquired on the immediate job over experience gained on earlier jobs. This hypothesis results from the operation of two forces. First is the development of human capital. Human capital acquired on a particular job has immediate application and thus should have a quick payoff. Human capital investments made through prior job experience may have limited

or tangential application to a later job and may obtain returns which are lower than that realized from immediate job experience. Time is the second force in operation. The value of both information and human capital investments deteriorate over time. Information about performance on earlier jobs may be discounted more heavily as more information about performance on the immediate job becomes available. Just as with machinery, human capital depreciates and therefore must be replenished through continual maintenance and reinvestment. Consider, for example, the decline in the value of keypunch operation skills over the past two decades.

Model results for the two measures of experience were in accord with expectations. The coefficient on prior job experience (*EXPER*1) was positive but not significantly different from zero. The coefficient on the length of employment on the immediate job was both positive and significant. Respondents earned an average return of $972 for each year of employment on the most recently held job. These results confirm the hypothesis that immediate job experience is more highly valued in the marketplace than earlier job experience.

The educational variable *EDUC*2 (highest educational level achieved by 1985) was insignificant in the 1985 income model. This does not imply, however, that advanced degrees yielded zero returns once the respondents had acquired some job experience. Recall from the first model that there was a $3,102 premium in starting income for an advanced degree. The premium carries into the 1985 income model through the starting income variable (*INC*1). For 1985, then, an advanced degree earned a premium of at least $1,002, which is the advanced degree carried over from the starting income model less the advanced degree "discount" in the 1985 income model ((0.563 × $3,102) − $744). The advanced degree premium for 1985 would be $1,746 (=0.563 × $3,102), considering the statistical result that 1985 incomes associated with the three levels *EDUC*2 were not significantly different from zero or each other.

The research hypothesized that the influence of job experience on salary rises with an individual's time in the labor force. Collective results on the job experience and education variables support this hypothesis. The increase in income from less than two years of experience on the immediate job (*EXPER*2) exceeded the 1985 income premium associated with advanced degrees. The findings show that the net returns to obtaining an advanced degree depend critically on the opportunity costs and length of the degree program. This result must be tempered, however, because the analysis did not account for possible differential income growth rates associated with levels of formal education. *MAJOR* was found to have a statistically insignificant influence on 1985 incomes, consistent with results for the starting income model.

Two variables (*SOUTH*2 and *URBAN*) were included in the 1985 income model to explain possible differences in income attributable to locational labor market conditions. *SOUTH*2, which indicated whether the 1985 job was located in one of thirteen southern states, was insignificant. A similar result was obtained in the starting income model. The second locational variable, *URBAN*, was significant. Parameter estimates showed that those situated in urban areas (large, medium, or small cities) earned expected mean incomes $3,332 higher than those in nonurban areas (outside a city or village, or on a farm or ranch). People tend to migrate toward places of employment that maximize returns to their investments in human capital. Because urban employment opportunities may offer greater financial returns, urban residence tends to be associated with higher income earnings. However, the real buying power of incomes between urban and rural residences may be nearly equivalent because of higher costs of living in urban areas.

Consistent with the first income model, the fringe benefit variable *PRFT* (profit sharing) was found to be significant. Those who participated in profit-sharing plans earned incomes $2,561 higher than those who did not. This income premium may be attributable to forces acting on both sides of the labor market. On the demand side, profit-sharing plans tend to be offered by larger and perhaps more progressive and profitable firms. Part of the higher earnings of such firms may be passed on to employees through both higher wages and profit sharing. On the supply side, aggressive individuals seeking to maximize incomes may be attracted to positions that offer profit sharing. If profit sharing is linked to employee performance, then such positions would tend to attract performance-oriented employees.

The provision of housing benefits (*HSG*2) did not have a statistically significant impact on 1985 incomes. This finding was consistent with results obtained in the starting income model.

Although parameter estimates suggested that women earned lower incomes than men during 1985, the difference was not statistically signif-

icant. Thus, gender-related differences in starting incomes appeared to decline with increased labor market experience. Effects of the *INC*1 variable, however, implied that males maintained a 1985 income advantage of at least $976 (0.563 × $1,733) over females.

Marital status was a significant determinant of 1985 income. Parameter estimates showed that married respondents earned an expected $2,421 more than those not married. Perhaps married individuals can better maximize their human capital investments because of the financial and emotional support provided by the spouse. Also, employers may perceive married employees to be more responsible and hence better investment risks.

In contrast to the starting income model, respondents' assessments of the need for particular skills for career improvement were found to contribute significantly to explaining the variation in 1985 incomes. Parameter estimates showed that those who ranked *ORAL* as much needed or essential had $4,279 higher mean 1985 incomes than those who ranked such skills as not or somewhat needed. The result reinforces the hypothesis that the use of oral communication skills tend to be associated with supervisory, managerial, or entrepreneurial level positions wherein financial compensations are higher (Broder and Houston).

In comparison, respondents who ranked a technical skill (*TECHNICAL*) as much needed or essential earned $5,386 less than those who ranked it as not or somewhat needed. This result, which was significant, confirms expectations that careers built on narrowly defined technical skills tend to be associated with lower incomes.

Implications

The labor market for graduates from colleges of agriculture is characterized by change and uncertainty. Because labor market information tends to be imperfect, employers and employees engage in a search process. The purpose of this study has been to better understand this search process by determining how individual characteristics, education, and occupational experiences influence the earnings of graduates from colleges of agriculture. This study concentrated particularly on changes in salary determinants that occur over the course of a person's career. The remainder of the discussion focuses on the implications for agricultural programs and for individual's careers.

Agricultural Curricula

Although recruitment of new students receives much attention from college administrators (Connor), retention of existing students represents an equally important dimension of addressing declining agricultural enrollments. Questionnaire results showed that fully one-fifth of the respondents either transferred to programs outside of agriculture or failed to obtain the bachelor's degree. Efforts to retain even a portion of these students may be more successful and cost effective than attempts to attract the same number of students from a diverse pool of incoming high school graduates and students enrolled in other programs.

As further evidence in support of retention programs in colleges of agriculture, the empirical results failed to identify significant salary differences attributable to the choice of major (agriculture, forestry, or other programs). In particular, one-time agricultural majors did not appear to enhance their future earnings by transferring to other colleges.

Recent articles about educational programs at land grant and other agricultural colleges have emphasized the need to broaden agricultural curricula (Schuh, Litzenberg and Schneider, Connor). The empirical results reported herein substantiate the proposition that colleges should provide broad-based training that maximizes individual adaptability to changing labor market conditions. Higher incomes for 1985 were associated with those who regarded oral communication skills as essential to their careers, while lower incomes were associated with those who rated a technical skill as essential to their careers. The results should not be interpreted superficially to suggest that the teaching of technical skills be eliminated from agricultural programs. Rather, the results reinforce the need to integrate the development of interpersonal skills into the college curriculum. Training in oral, written, and interpersonal skills need not be relegated to other departments but should be built into disciplinary course work and related extracurricular activities.

This study found that the salary premiums associated with advanced education tended to subside with career maturation. These findings suggest that curriculum design and educational reform may be of greatest benefit to graduates early in their careers and may have less influence on graduates later in their careers. Thus, colleges of agriculture should be sensitive to the dynamics of labor market information and em-

phasize curriculum reforms having swift and certain benefits in the labor market.

Career Strategies

This study found that educational achievement was a significant determinant of income on the first job but tended to diminish in importance on later jobs. From a benefit-cost perspective, the decision to pursue formal education at any level must rest ultimately on tradeoffs between financial goals, other personal objectives, and opportunity costs associated with enrollment in the educational program (Broder and Deprey). Given that personal emphasis on pay differs across individuals, the importance of both monetary and nonmonetary career objectives must be recognized. Indeed, the notion of personal benefit-cost assessment applies to virtually any decision over which individuals have some control. To take a job with a profit-sharing plan, for instance, an individual may have to bear the opportunity cost of forgoing a different position in a more desirable location. This study makes no pretense of offering advice on how individuals should weigh the intrapersonal tradeoffs associated with human capital investment decisions.

Because inherent personal characteristics may affect an employee's mobility, demographic variables were identified as potential determinants of earnings. This study found gender to be a significant determinant of starting salaries, though not of later earnings. Given this trend, the gender-wage differential appeared to lessen over time. This declining differential was attributed to the emergence of more reliable market information on the marginal value product of female workers. Thus, the results provide an encouraging outlook for women considering post-college careers in agriculture.

Starting incomes were found to have a positive and significant impact on later-year earnings while school-related attributes tended to diminish with time. Similarly, immediate job experience was a more important income determinant than was experience on previous jobs. These findings suggest the value of market information tends to deteriorate or have a limited shelf life over time as new information on job performance becomes available. The obvious and perhaps predictable implication is that employees striving for financial success cannot "rest on their laurels." As careers mature, remuneration based on observed job performance can outweigh either early successes or failures.

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The Effects of State Farm Relief Legislation on Private Lenders and Borrowers: The Experience of the 1930s

Randal R. Rucker

The effects on private lenders and borrowers of farm relief programs that alter the enforceability of debt contracts are investigated. Evidence from the 1930s indicates that state relief legislation that altered debt contracts to the detriment of lenders substantially reduced the supply of loans and had different effects on different types of private lenders. This past experience suggests that, although such measures as moratoria on farm foreclosures and the recently enacted Chapter 12 bankruptcy law may provide relief for some farmers, they may also result in substantial reductions in the supply of agricultural credit.

Key words: agricultural credit, bankruptcy law, farm policy, foreclosure moratoria.

A significant number of farmers have suffered severe financial stress in recent years (Boehlje, Thamodaran, and Barkema; Melichar). Predicting the likely impacts of the various proposals for alleviating these problems is difficult. The most common approach is to estimate the effects of different policy options using simulation models (Barry 1986; Boehlje, Thamodaran, and Barkema; Pederson et al.). An alternative approach is to look to the past for similar experiences in order to obtain useful insights about the present situation. Changes in agricultural financial markets over time preclude using historic information to make precise predictions about contemporary issues. However, the past can provide useful insights into the general magnitudes and directions of the responses to current policy options.

The historical approach is used in this paper to examine the effects of government-imposed measures that alter the enforceability of agricultural debt contracts. Recent examples of such measures include the Chapter 12 bankruptcy law that went into effect in 1986 and moratoria on farm foreclosures like those enacted in Iowa in 1985 and considered by legislators in other farm states. Such measures may provide short-term relief to some farmers. However, they also impose costs on lenders and may reduce the supply of credit to the agricultural sector.[1]

The period studied in this paper is the 1930s, the most recent period (prior to the early 1980s) of severe agricultural distress in the United States. Included among the programs instituted in the 1930s to provide relief for the farm sector were state-legislated moratoria on farm foreclosures. This paper examines the effects of these moratoria and other types of state relief programs on the supply of farm loans in the 1930s.

The use of data from the past to glean insights into current agricultural finance problems has not been widely employed. Shepard and Collins used time-series data to investigate the determinants of aggregate farm bankruptcy rates. They included a general agricultural policy variable (government support payments as a proportion of all farm revenues) as an explanatory variable

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[1] Evidence consistent with such a response to the Chapter 12 bankruptcy law was cited shortly after its enactment. See "Farm Bankruptcy Law Halts Some Loans and Stirs Fears About Farmers' Credit," *The Wall Street Journal,* 19 Jan. 1987.

in their empirical analysis but did not investigate the effects of particular programs on bankruptcy rates. Rucker and Alston used data from the period 1929–40 to investigate the effects of government programs on rates of farm failure during the 1930s; they found that state-legislated moratoria did reduce farm failure rates. Alston (1984) used state-level cross-sectional data to investigate the causes and consequences of state-legislated moratoria during the 1930s. His reduced-form estimates indicated that moratoria led to significant reductions in the quantity of private loans. The present paper extends Alston's work by estimating the structural and interregional effects of state relief legislation on different types of private lenders.

This paper is organized as follows. Mortgage foreclosure procedures and state relief legislation passed during the early 1930s are described in the next section; then, a system of demand and supply equations for loans from government and private lenders is presented, the effects of relief legislation are predicted, the empirical specification is described, and the results of the empirical analysis are reported. The concluding section considers the implications of the results for recent farm problems.

The Mortgage Foreclosure Process and State Relief Legislation in the 1930s

If an individual borrower became delinquent on his mortgage payments, the lender decided whether to grant the borrower an extension or to foreclose on the mortgage. If the lender chose to foreclose, then he initiated the process for selling the property.[2] The sale was conducted through an auction in which any interested parties, including the original lender, could bid on the property. If the winning bid exceeded the amount due in principal and interest on the first mortgage, then the lender received payment and the remaining funds were divided among other lenders holding liens on the property. Any funds remaining went to the borrower. In some states if the winning bid was less than the debt owed on the first mortgage, the lender could sue for a deficiency judgment for the difference.

After the auction, the borrower often was granted a redemption period. If, during this period, he was able to pay off the mortgage plus any accrued costs, he could recover title to the property. If the borrower (or a junior lender) did not pay off the mortgage during the redemption period, then the title to the property was transferred to the high bidder at the auction.

Prior to the Great Depression, there were isolated instances of states passing legislation during periods of depressed earnings to provide relief to debtors from their contractual loan obligations (Alston 1984, Friedman, Woodruff). The experience of the 1930s was unique, however, in two respects. First, it was unique in its magnitude: more than half the states enacted relief legislation. Second, the constitutionality of this type of relief legislation was upheld by the U.S. Supreme Court for the first time.[3]

State-legislated relief for debtors during the 1930s generally took three forms: (*a*) moratoria on foreclosures, (*b*) extension of the redemption period, and (*c*) limitation (or abolishment) of deficiency judgments. Legislation of the first type generally gave the courts discretionary power to postpone foreclosure proceedings over a specified period. Postponement periods varied in duration across states and sometimes were extended when the initial legislation expired. Foreclosures were not completely prohibited under these laws. Borrowers were usually required to make certain payments to lenders—interest, taxes, and court-specified rents.[4] Failure to make these payments could lead to foreclosure.

The second type of relief legislation temporarily increased the length of redemption periods. This type of legislation imposed costs on lenders by delaying the time at which clear title could be obtained by the new owner. Although the borrower was required to make court-specified payments to the lender during this redemption period, these payments were less than payments received under normal circumstances (Woodruff, pp. 114–15). In addition, under these arrangements borrowers were inclined to neglect the property and may have been willfully destructive in some instances.

The third type of relief legislation restricted creditors' rights to deficiency judgments. In some states, e.g., North Dakota, such judgments were

[2] Foreclosure could be accomplished either by advertisement (power of sale) or by court action (judicial foreclosure). The procedure for initiating a foreclosure differed somewhat depending on the foreclosure method chosen. Woodruff (appendix A) indicates that during the 1930s most states enacted legislation requiring foreclosure by action.

[3] The landmark case on relief legislation was *Home Building and Loan Association* v. *Blaisdell et al.*, in which the constitutionality of relief legislation enacted in Minnesota was upheld.

[4] Rents paid under these arrangements tended to be less than those paid by tenants renting under normal circumstances (Woodruff, pp. 114–15).

abolished. In others, the dollar value of deficiency judgments was limited, often by setting a minimum auction price for the property.

Supply and Demand for Farm Mortgage Loans

If the three types of relief legislation described above were viewed by lenders as an attenuation of valued rights in future mortgage contracts, then decreases in the supply of loans are expected following the enactment of such legislation. This and related issues involving differences among lenders and across regions in the effects of relief legislation are investigated using the following model of the supply and demand for farm mortgage loans.

Supply of Farm Mortgage Loans

$$Q^s_{GOV} = \alpha_0 + \overset{(+)}{\alpha_1}FDRDUM + \overset{(0)}{\alpha_2}STRESS + \overset{(+)}{\alpha_3}(FDRDUM{*}STRESS) + \epsilon_1 \tag{1}$$

$$Q^s_{INDIV} = \beta_0 + \overset{(-)}{\beta_1}RLFLEG + \overset{(+)}{\beta_2}INTINDIV + \overset{(-)}{\beta_3}INTALT + \overset{(+)}{\beta_4}SZINDIV + \overset{(-)}{\beta_5}DEBT/VALUE + \epsilon_2 \tag{2}$$

$$Q^s_{BANK} = \gamma_0 + \overset{(-)}{\gamma_1}RLFLEG + \overset{(+)}{\gamma_2}INTBANK + \overset{(-)}{\gamma_3}INTALT + \overset{(+)}{\gamma_4}SZBANK + \overset{(-)}{\gamma_5}DEBT/VALUE + \epsilon_3 \tag{3}$$

$$Q^s_{INSUR} = \delta_0 + \overset{(-)}{\delta_1}RLFLEG + \overset{(+)}{\delta_2}INTINSUR + \overset{(-)}{\delta_3}INTALT + \overset{(+)}{\delta_4}SZINSUR + \overset{(-)}{\delta_5}DEBT/VALUE + \epsilon_4, \tag{4}$$

where Q^s_{GOV}, Q^s_{INDIV}, Q^s_{BANK}, and Q^s_{INSUR} are the quantities (dollar value) of farm mortgage loans supplied by government lenders, individuals, banks, and insurance companies in state i in year t. The other variables are defined in table 1.

Predicted signs for the coefficients of the explanatory variables are indicated in parentheses above the coefficients. The hypothesized supply of government loans is a function of whether President Franklin D. Roosevelt was in office (*FDRDUM*) and the level of financial stress (*STRESS*), *FDRDUM* has a positive coefficient, reflecting the increase in federal lending following Roosevelt's election in 1932. Prior to 1933, the mandate of federal credit agencies was to supply loans in regions where private funds were not readily available.[5] If the activities of these agencies did not vary with the degree of farm distress prior to 1933, the coefficient on *STRESS* is zero. After 1932, a stated objective of federal lending agencies was to provide funds to those farmers suffering the most; thus, the coefficient on the interactive variable (*FDRDUM*STRESS*) is positive.

In the three private supply equations, (2)–(4), the coefficient on the relief legislation variable (*RLFLEG*) is negative, indicating that private lenders will decrease their activities as mortgage contracts are altered to their detriment. The predicted coefficients on the respective own-interest rate variables (*INTINDIV, INTBANK,* and *INTINSUR*) are positive, reflecting upward sloping loan supply curves. An increase in the rate of return on alternative investments will reduce the supply of farm mortgage loans; hence the coefficients on *INTALT* are negative. If there are fixed costs associated with issuing loans, then an increase in average loan size will reduce transaction costs (per dollar of loans issued), thereby increasing the supply of loans. Hence, positive coefficients are predicted on *SZINDIV,*

[5] Federal lending agencies include the federal land banks and the Land Bank Commissioner. For a detailed account of the activities of these agencies during the 1930s and the changes that were instituted under Roosevelt, see Horton, Larsen, and Wall.

SZBANK, and *SZINSUR*. An increase in farm leverage is predicted to decrease the supply of loans from private lenders; hence, the coefficients on *DEBT/VALUE* are negative.

Demand for Farm Mortgage Loans

The following equations,

$$(5) \qquad Q^d_{GOV} = Q^s_{GOV} \text{ if } INTGOV < INTPRIV$$
$$= 0 \text{ otherwise}$$

$$(6) \qquad Q^d_{PRIV} = \tau_0 + \underset{(\pm)}{\tau_1 RLFLEG} + \underset{(-)}{\tau_2 INTPRIV} + \underset{(+)}{\tau_3 DEBT/EEARN} + \underset{(-)}{\tau_4 Q_{sGOV}} + \epsilon_6$$

$$(7) \qquad Q^d_{INDIV} = \phi_0 + \underset{(-)}{\phi_1 INTINDIV} + \underset{(+)}{\phi_2 INTBANK} + \underset{(+)}{\phi_3 INTINSUR} + \underset{(+)}{\phi_4 Q^d_{PRIV}} + \epsilon_7$$

$$(8) \qquad Q^d_{BANK} = \theta_0 + \underset{(+)}{\theta_1 INTINDIV} + \underset{(-)}{\theta_2 INTBANK} + \underset{(+)}{\theta_3 INTINSUR} + \underset{(+)}{\theta_4 Q^d_{PRIV}} + \epsilon_8$$

$$(9) \qquad Q^d_{INSUR} = \Omega_0 + \underset{(+)}{\Omega_1 INTINDIV} + \underset{(+)}{\Omega_2 INTBANK} + \underset{(-)}{\Omega_3 INTINSUR} + \underset{(+)}{\Omega_4 Q^d_{PRIV}} + \epsilon_9,$$

where Q^d_{GOV}, Q^d_{INDIV}, Q^d_{BANK}, Q^d_{INSUR}, and Q^d_{PRIV} are the quantities of farm mortgage loans demanded from government lenders, individuals, banks, insurance companies, and private lenders, respectively, in state *i* in year *t*. The other variables are defined in table 1.

In the demand for government loans equation (5), borrowers are assumed to demand as many funds as federal credit agencies will provide, as long as the interest rate on government loans is less than the interest rate on private loans [which was generally the case following the advent of Roosevelt's New Deal programs (USDA 1938, 1939)].

Borrowers' demand for loans from private lenders is modeled as a two-step process. In the first step [equation (6)] farmers decide how much to borrow from private lenders as a group. This decision is based on average interest rates on loans available from private lenders (as well as other factors discussed below). In the second step, farmers decide how to allocate their borrowing among the three types of private lenders. This decision is based on the relative interest rates available from the three types of lenders.[6]

In the first-step private demand equation (6), the predicted coefficient of the relief legislation variable is uncertain. On the one hand, the relief legislation of the early 1930s increased the attractiveness of mortgage loans to borrowers. On

[6] An alternative "one-step" model of demand is to specify the demand for loans from each type of lender as a function of relief legislation, the ratio of debt to discounted expected future income, the supply of government loans, and the interest rates of all three lenders. The two-step approach is used because it provides more precise coefficient estimates. The choice between these two specifications has no effect on the empirical estimates of the impact of state relief legislation on the supply of loans.

Table 1. Definitions of Variables

FDRDUM—zero-one dummy variable to indicate whether President Franklin D. Roosevelt was in office.
STRESS—extent of farm financial stress in state *i* as of year *t*.
*FDRDUM**STRESS*—interactive term between *FDRDUM* and *STRESS*.
RLFLEG—zero-one dummy variable to indicate whether relief legislation was in effect in state *i* in year *t*.
INTINDIV, *INTBANK*, and *INTINSUR*—average rates of interest charged on farm-mortgage loans recorded in state *i* in year *t* by individuals, banks, and insurance companies.
INTALT—interest rate available on alternative investments in year *t*.
SZINDIV, *SZBANK*, and *SZINSUR*—average size (dollar value) of loans issued in state *i* in year *t* by individuals, banks, and insurance companies.
DEBT/VALUE—ratio of total farm debt to the value of farm assets (land and buildings) in state *i* in year *t*.
INTGOV and *INTPRIV*—average rates of interest charged on farm mortgage loans recorded in state *i* in year *t* by federal lenders and by private lenders as a whole.
DEBT/EEARN—ratio of total farm debt to the discounted value of expected future net farm income in state *i* in year *t*.

the other hand, borrowers observed that state governments now could change the terms of existing contracts between private parties. If borrowers feared that future relief legislation might be designed to benefit lenders rather than borrowers, then the uncertainty would increase concerning the security of their property rights in future mortgage contracts. This would lead to a reduction in loan demand. The relative magnitudes of these offsetting effects is an empirical question.

An increase in the average rate of interest on private loans will lead to a reduction in the quantity of private loans demanded; hence, the coefficient on *INTPRIV* is negative. An increase in the level of debt relative to the present value of the expected future flow of income will decrease the demand for loanable funds, implying that the coefficient on *DEBT/EEARN* is negative.

The coefficient on Q^s_{GOV} in equation (6) is bounded by 0 and -1, with the actual value determined by the allocation of government loans among private borrowers. A value of zero indicates that all the low interest rate government loans were allocated to borrowers not willing to pay the market-clearing interest rate. At the other extreme, if all government loans were allocated to borrowers willing to borrow at market interest rates, then the demand for private loans would shift to the left by the amount of the government loans; that is, the value of the coefficient on Q^s_{GOV} would be -1. For intermediate cases this coefficient is between 0 and -1.[7]

In the second-step demand equations, (7)–(9), an increase in the interest rate on loans from a particular lender will decrease the quantity of loans demanded from that lender, and the coefficients ϕ_1, θ_2, and Ω_3 will be negative. If loans from different types of lenders are substitutes, an increase in the rate charged by one lender will increase the demand for loans from other lenders and the coefficients ϕ_2, ϕ_3, θ_1, θ_3, Ω_1, and Ω_2 will be positive. An increase in the total demand for private loans will result in increased demand for loans from each type of lender; hence, the coefficients on Q^d_{PRIV} in equations (7)–(9) are positive.

Additional Issues

The model of supply and demand for agricultural loans presented above allows the investigation of whether relief legislation had different effects on different types of private lenders and in different regions. The lender effects are indicated by differences in the estimated coefficients on *RLFLEG* in equations (2)–(4). To illustrate, relief legislation might have affected insurance companies less than individuals and banks for two reasons.

First, borrowers are more likely to borrow from a lender if they believe that lender is less likely to foreclose when loan problems occur. Lenders, therefore, have an interest in establishing "goodwill capital," perhaps by granting extensions to farmers experiencing loan delinquences caused by factors beyond their control. The costs to lenders of granting extensions rather than foreclosing and reselling the property differ among lenders. Insurance companies, unlike most local banks and individual lenders, normally had portfolios that included mortgage loans from several regions (Woodruff, p. 49). Because lending problems varied among regions during the 1930s, delinquent loans in a particular area would have a smaller (proportional) effect on insurance companies than other lenders. In addition, insurance companies were better diversified than other lenders, in that a smaller portion of their portfolios was allocated to mortgage loans. If insurance companies did have to turn to capital markets to compensate for delinquent payments, their cost of funds likely was lower than for individuals and local banks. Thus, insurance companies were more likely than other lenders to grant extensions to delinquent borrowers. In turn, they likely were less affected by relief legislation than other lenders.[8]

Second, the regional orientation of insurance companies and the long distances between central offices and borrowers' locations increased the cost of monitoring borrower performance. As a result, insurance companies tended to make larger, lower-risk loans (Alston forthcoming, Woodruff). Because lower-risk borrowers were less likely to experience loan delinquencies, foreclosure rates on insurance company mortgages should have been lower, and the costs imposed on them by relief legislation would be lower than for other lenders.

Another issue concerns differences in the impacts of relief legislation across regions that may

[7] See Rucker for further discussion of this issue.

[8] Woodruff commented several times on the insurance companies' efforts to be lenient toward borrowers during the early 1930s. Alston speculated that "individuals—and perhaps local banks—being less diversified and facing a more severe income constraint than insurance companies and federal financial institutions had more of an incentive to foreclose" (1984, p. 451).

have resulted from interstate differences in the provisions and enforcement of the legislation. Because the laws differed in numerous dimensions and because court enforcement was not uniform across states, the severity of the various states' legislation cannot be quantified. However, a subjective measure of the relative severity of legislation was recently provided by Woodruff. He suggested that from the perspective of banks and individual lenders, the most restrictive relief legislation was enacted in the two Dakotas, Minnesota, and Wisconsin.[9] Thus, the impacts of relief legislation were likely greater in these states than elsewhere.

Empirical Specification

The system of equations (1)–(9) is estimated using pooled time-series cross-sectional data for the period 1930–35. The estimation procedure uses the dummy variable model described by Judge et al. (pp. 478–88) in a simultaneous equations setting using two-stage least squares. Cross-sectional units are distinguished by including zero-one state dummy variables.

Insurance companies did not issue farm loans in all states in the 1930s. Because these companies were an important source of loanable funds in many states and because the impact of relief legislation on these companies is of interest, the data set is restricted to the thirty-two states in which data for interest rates on insurance company loans are available for the years 1930–35.[10] Of these states, twenty-two legislated one or more of the three types of relief legislation discussed above (see Rucker, table 1, for specifics).

Although annual data on the loan quantities (dollar value) of federal lending agencies (*QGOV*) are available (U.S. Congress 1931–33; Farm Credit Administration 1934–36; Horton, Larsen, and Wall, table 78, p. 245), no data on the annual quantity of loans issued by private lenders were published. Estimates of these quantities are constructed using data on federal loan quantities and on the percentage of loans issued by federal and private lenders (USDA 1940b).

In the government supply equation, *FDRDUM* is a zero-one dummy variable that is included to measure the impacts of Roosevelt's programs on the supply of federal credit. This variable is assigned a value of one in 1934 and 1935, and a value of zero otherwise.[11] Two measures of financial stress are used. *STRESS*1 is the simple average of earnings in years t-1 and t-2 (USDA Jan. 1946). A reduction in this variable measures an increase in "short-run" stress, or cash shortfalls. To control for interstate differences in the levels of state farm earnings, earnings in state i in year t are divided by earnings in state i during a base period (the average of earnings in 1924 and 1925). *STRESS*2 is a simple average of the ratio of an index of total farm debt (Horton, Larsen, and Wall) to the value of land and buildings (Regan and Johnson) in years t-1 and t-2. An increase in this variable indicates greater "long-run" stress, or leverage problems.

The variable *RLFLEG* is assigned a value of one if any of the three types of state relief legislation were in effect in a given state in a given year. Alston's analysis was limited to the effects of legislation that postponed foreclosures (moratoria). The discussion above of the different types of state relief legislation suggests that the effects of legislation extending redemption periods and limiting deficiency judgments may also be important. The estimation of several specifications designed to measure separately the effects of these different types of relief legislation suggest that the data are not capable of distinguishing their separate effects. This result is attributed to the fact that states often enacted two or three types of relief legislation at (roughly) the same time (U.S. Congress, April 1936; USDA, June 1934).

Annual data on interest rates and average loan sizes are obtained directly from USDA reports (1938, 1939, 1940a). The variable used to measure leverage (*DEBT/VALUE*) is the ratio of an index of farm mortgage debt to an index of land values. The proxy used for the rate of return on alternative investments in year t (*INTALT*) is the rate of interest on commercial paper in year t (Federal Reserve bulletins).

In the first-step demand equation, the proxy used for the discounted value of expected earnings (*EEARN*) is the value of farm land and buildings in state i in year t. Thus, the same proxy is used for *DEBT/EEARN* in this equa-

[9] Letter from Archibald Woodruff, dated 12 Aug. 1982, to Lee Alston and telephone conversation between Alston and Woodruff.

[10] There are a few instances in which data on interest rates on insurance loans are not available for a particular year and in which the average interest rate on government loans exceeded the interest rate on loans from one of the three classes of private lenders. To maintain consistency with the system described by equations (1)–(9), these observations are deleted from the data set.

[11] Preliminary analysis indicated that the specification of the government supply equation was improved by assigning *FDRDUM* a value of one for 1934 and 1935 rather than for 1933–35. This suggests that it was a year after Roosevelt took office before his programs had measurable effects.

tion as for *DEBT/VALUE* in the supply equations.

Estimation Results

Preliminary regression results for the supply equations (1)–(4) suggested that interest rates on loans of insurance companies might be exogenous. Because insurance companies tended to operate on a larger scale than other private lenders and at a national rather than a local level (Woodruff, p. 49), interest rates on their loans may have been exogenous to borrowers in a particular state. A Wu-Hausman test failed to reject the null hypothesis that these interest rates were predetermined.[12] Given this result, the interest rate on loans by insurance companies is not affected by shifts in the state-level demand for loans from insurance companies but may be influenced by relief legislation, interest rates on alternative investments, and so forth. The system of equations (1)–(9), therefore, is estimated by replacing equation (4) with an equation in which the interest rate on insurance company loans is regressed on the variables *RLFLEG, INTALT, DEBT/VALUE*, and *SZINSUR*. Extension of the logic presented in the discussion of the supply equations suggests that the estimated coefficients on the first three of these variables are positive and that the coefficient on *SZINSUR* is negative. Estimation results are displayed in table 2.[13]

In the government supply equation, the estimated coefficient on *FDRDUM* indicates a statistically significant increase in new loans issued by government credit agencies following 1933. The statistically insignificant coefficient on the first measure of stress, *STRESS*1, suggests that before 1934 federal credit agencies did not respond to differences in recent earnings levels, while the coefficient on *STRESS*2 indicates a significant increase in government loans in response to adverse leverage experience. The coefficient on the interactive variable *FDRDUM*STRESS*1 indicates a highly significant change after 1933 in the responsiveness of federal credit agencies to shortfalls in recent earnings. The coefficient on *FDRDUM*STRESS*2 suggests a marginally significant change in responsiveness to differences in leverage experience (p-value = .15).

[12] The t-ratio from this test is equal to .85. See Thurman for discussion of the use of this statistical test.

[13] Data from all thirty-two states in the sample are used to obtain the coefficient estimates in table 2.

In the supply equations for individual and bank lenders, the coefficients on *INTALT* and *DEBT/VALUE* all have the predicted negative signs, while the coefficients on loan size and own-interest rate have the predicted positive signs. The coefficients on the relief legislation dummy variables are negative and statistically significant in both equations. The estimated coefficients on the *RLFLEG* variables indicate that (*ceteris paribus*) state relief legislation resulted in reductions in the annual supply of loans from individual lenders and banks of $2,512,000 and $1,867,000, respectively. These amounts represent 31% and 35% of the average annual quantity of mortgage loans issued by individuals and banks. These results suggest that relief legislation resulted in substantial reductions in the supply of agricultural credit from banks and individual lenders.

In the equation for insurance company interest rates, as predicted, the coefficients on the interest rate on alternative investments (*INTALT*) and leverage (*DEBT/VALUE*) are positive and significant. The coefficient on the relief legislation dummy variable is positive but not significant.

In the first-step demand equation in table 2, the estimated coefficients on *INTPRIV* and *DEBT/EEARN* have the predicted negative signs. The estimated coefficient on Q^{*}_{GOV} is significantly less than zero and greater than -1. Apparently, some of the low interest government loans were allocated to borrowers willing to borrow at market interest rates, i.e., federal loans "crowded out" some privately supplied loans. A coefficient significantly greater than -1 suggests that a portion of government loans was granted to borrowers who were not willing to pay the market-clearing interest rates that would have prevailed on private loans in the absence of government credit. The estimated coefficient on *RLFLEG* is negative and statistically significant. This result suggests that the demand-reducing effects of the 1930s legislation (from increased uncertainty concerning property rights in private loan agreements) outweighed any demand-increasing effects (from the pro-debtor nature of the legislation).

In the second-step demand equations (whose estimated coefficients are not shown in table 2), only two of the nine estimated coefficients on the interest rate variables are significantly different from zero. The inability to sort out the individual effects of the three interest rate variables is attributed to the high degree of collinearity among them (the three pairwise correla-

Table 2. Determinants of the Demand and Supply of Government and Private Farm Mortgage Loans

Supply Equations

Government:
$$Q^s_{GOV} = \underset{(1.03)}{-30879} + \underset{(4.24)}{55394}\,FDRDUM + \underset{(.56)}{4406}\,STRESS1 + \underset{(2.12)}{34597}\,STRESS2 - \underset{(5.63)}{113332}\,(FDRDUM*STRESS1) + \underset{(1.06)}{9249}\,(FDRDUM*STRESS2)$$
$R^2 = .6764$

Individuals:
$$Q^s_{INDIV} = \underset{(1.29)}{21652} - \underset{(2.42)}{2512}\,RLFLEG + \underset{(1.07)}{2896}\,INTINDIV - \underset{(1.88)}{932}\,INTALT - \underset{(5.15)}{10456}\,DEBT/VALUE + \underset{(2.92)}{3.65}\,SZINDIV$$
$R^2 = .8619$

Banks:
$$Q^s_{BANK} = \underset{(3.43)}{36423} - \underset{(2.15)}{1867}\,RLFLEG + \underset{(1.32)}{1934}\,INTBANK - \underset{(1.41)}{506}\,INTALT - \underset{(4.55)}{7884}\,DEBT/VALUE + \underset{(1.57)}{.68}\,SZBANK$$
$R^2 = .8841$

Insurance companies:
$$INTINS = \underset{(15.1)}{5.57} + \underset{(.77)}{.061}\,RLFLEG + \underset{(4.73)}{.115}\,INTALT + \underset{(1.99)}{.315}\,DEBT/VALUE + \underset{(.16)}{(2.1E\text{-}06)}\,SZINS$$
$R^2 = .7248$

First-Step Demand Equation

Total private:
$$Q^d_{PRIV} = \underset{(5.58)}{142700} - \underset{(2.27)}{4596}\,RLFLEG - \underset{(1.08)}{3766}\,INTPRIV - \underset{(6.12)}{23131}\,DEBT/EEARN - \underset{(1.76)}{.116}\,Q^s_{GOV}$$
$R^2 = .8721$

Note: t-ratios are in parentheses.

tion coefficients ranged from .6 to .8).

The system whose estimates are presented in table 2 constrains slope coefficients to be equal across all states. This constraint is relaxed, and interregional differences in the impacts of state relief legislation are investigated by estimating different systems of equations for different regions. Table 3 contains the coefficient estimates and t-ratios for the *RLFLEG* variables for each of the seven regions in which insurance companies were active.

The first two columns in table 3 show the estimated effects of relief legislation on the supply of loans from individuals and banks. Ten out of fourteen of the coefficients in these columns are negative, with seven of them negative and statistically significant at a 10% level. The third column indicates that in only one of the seven regions did relief legislation have a positive and statistically significant impact on the interest rate on loans from insurance companies.

In all of the seven regions, the estimated coefficient on the government supply variable in the first-step demand equations (not shown in table 3) is significantly greater than -1, implying (as did the coefficient in table 2) that a portion of the government credit was allocated to borrowers not willing to borrow from private lenders. The coefficient on this government supply variable is significantly less than zero in three regions (West North Central, Mountain, and Pacific) indicating that, in those regions, increases in government-supplied credit in the early 1930s "crowded out" private loans. Also, the estimated coefficient on the relief legislation variable in the first-step demand equation is negative in six of the seven regions but is statistically significant in only two regions (Pacific and East South Central).

Tables 2 and 3 provide information concerning the magnitude and significance of shifts in the supply curves of private lenders resulting from the relief legislation in various states. Another useful measure is the impact of these laws on the market shares of private lenders. The market share of federal credit agencies increased during the 1930s because of the expanded credit programs instituted by Roosevelt and because of the reduced lending by private creditors resulting from state relief legislation. Estimates of the effects of state relief legislation on the percentage of loans issued by individuals, banks, and in-

Table 3. Effects of Relief Legislation on the Supply of Private Mortgage Loans in Seven Regions

Region	$\frac{\partial Q^s_{INDIV}}{\partial RLFLEG}$	$\frac{\partial Q^s_{BANK}}{\partial RLFLEG}$	$\frac{\partial INTINS}{\partial RLFLEG}$
East North Central	−5964	−1544	−.144
	(1.75)[a,b]	(.50)	(.94)
West North Central	−7214	−4336	−.162
	(1.54)[a]	(2.08)[a]	(.88)
South Atlantic	−2074	−1624	−.078
	(.90)	(.89)	(.41)
East South Central	−6476	−9052	−.241
	(3.22)[a]	(2.30)[a]	(1.05)
West South Central	169	1976	.555
	(.06)	(1.03)	(1.88)[a]
Mountain	4990	2033	−.063
	(2.15)	(2.42)	(.36)
Pacific	−15,597	−13,024	−.289
	(6.64)[a]	(5.38)[a]	(.69)

Note: Individual and bank loans were made in all states. Those states in each region in which insurance companies also operated are,
East North Central: Ohio, Indiana, Illinois, Michigan, and Wisconsin.
West North Central: Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Kansas.
South Atlantic: Maryland, Virginia, North Carolina, South Carolina, and Georgia.
East South Central: Kentucky, Tennessee, Alabama, and Mississippi.
West South Central: Arkansas, Louisiana, Oklahoma, and Texas.
Mountain: Montana, Idaho, Colorado, and Arizona.
Pacific: Washington, Oregon, and California.
Of these states, relief legislation was passed in Ohio, Illinois, Michigan, Wisconsin, Minnesota, Iowa, North Dakota, South Dakota, Nebraska, Kansas, North Carolina, South Carolina, Alabama, Mississippi, Louisiana, Oklahoma, Texas, Montana, Idaho, Arizona, and California.

[a] Columns 1, 2: significantly negative at the 10% level (one-tailed test). Column 3: significantly positive at the 10% level (one-tailed test).

[b] t-ratios are in parentheses.

surance companies are presented in table 4. These estimates are the reduced-form coefficient estimates from a system of structural equations like (1)–(9) in which quantities of loans supplied by and demanded from different lenders have been replaced with percentages of loans supplied by and demanded from those lenders.

The rows of table 4 contain the estimated coefficients on the *RLFLEG* variable for each of the seven regions. The estimated effect of relief legislation on the percentage of loans issued by private lenders (shown in the 4th column) is negative in all the regions. Across the seven regions, the average reduction in the share of private lenders (or the increase in the share of federal credit agencies) resulting from state relief legislation is 20.17%. The average reductions in the shares of individuals, banks, and insurance companies are 14.11%, 5.87%, and .20%, respectively.

The prediction that banks and individual lenders were affected more than insurance companies by the state relief legislation of the 1930s is supported by the empirical estimates. In tables 2 and 3, the supply of credit from banks and individual lenders generally decreases, while the rate of interest on insurance company loans does not increase significantly as a result of relief legislation. Although the estimates reported in table 4 are reduced-form estimates, their ranking is consistent with the structural hypothesis that insurance companies were affected less by relief legislation than banks or individuals.

Woodruff observed that, from the perspective of banks and individual lenders, states in the East North Central and West North Central regions (North and South Dakota, Minnesota, and Wisconsin) passed the most restrictive relief legislation. The prediction that lending by banks and individual lenders in these states should experience the greatest reduction receives mixed support from the estimates reported in tables 3 and 4. In table 3 the reported coefficients indicate that the supply of loans from both individuals and banks in the West North Central region fell significantly. In the East North Central region, only the reduction in the supply of loans from individuals is significant. In table 4, the estimated reduction in the percentage of loans issued by banks and individual lenders is the sum

Table 4. Effects of Relief Legislation on Market Shares of Private Mortgage Loans

Region	$\frac{\partial\%INDIV}{\partial RLFLEG}$	$\frac{\partial\%BANK}{\partial RLFLEG}$	$\frac{\partial\%INSUR}{\partial RLFLEG}$	$\frac{\partial\%PRIV^{a}}{\partial RLFLEG}$
East North Central	−29.65 (4.77)[b]	−6.17 (1.77)[b]	10.91 (3.90)	−24.91
West North Central	−24.55 (4.61)[b]	−8.16 (1.91)[b]	−4.39 (.92)	−37.10
South Atlantic	−10.51 (1.94)[b]	−8.03 (1.53)[b]	−1.51 (1.36)[c]	−20.05
East South Central	−8.82 (.71)	−2.06 (.28)	−3.56 (.76)	−14.44
West South Central	−10.31 (2.08)[b]	3.62 (.84)	.34 (.11)	−6.35
Mountain	−10.29 (2.03)[b]	−11.48 (3.14)[b]	−3.09 (1.22)[c]	−24.86
Pacific	−4.64 (.65)	−8.78 (2.10)[b]	−.08 (.01)	−13.5
Average	−14.11	−5.87	−.20	−20.17

Note: *t*-ratios are in parentheses.
[a] The numbers in this column are obtained by summing the numbers in the first three columns.
[b] Significantly negative at the 10% level (one-tailed test).
[c] Significantly negative at the 15% level (one-tailed test).

of the entries in the first two columns. These estimated reductions are substantially greater in the East North Central and West North Central regions (−35.82 and −32.71) than in the other regions.

Concluding Comments

Government programs often have effects other than those predicted by their proponents. This appears to be true for state farm relief legislation enacted in the 1930s. Although Rucker and Alston indicate that this legislation had the desired effect of reducing farm failure rates, the present paper suggests that this legislation also resulted in significant reductions in the supply of loans from certain types of private lenders. Clearly, the structure of agriculture and of farm credit markets has changed since the 1930s. Farms are now larger and more highly leveraged, individual lenders and banks hold a smaller share of the outstanding debt, insurance companies lend almost exclusively to large commercial farms, the role of the Farm Credit System is larger, and the Farmers Home Administration is a major presence.

Given these differences, what lessons are learned from the 1930s experience? Certainly, the incentives have not changed for private lenders to compare the attributes of alternative investments and to modify their portfolios in response to changes in the relative attractiveness of different investments. Therefore, a primary lesson from the 1930s is that government-imposed measures to make agricultural debt contracts less attractive to lenders will reduce the supply of credit from private lenders. If the current responsiveness of lenders to such measures is similar to their responsiveness in the 1930s, then these reductions in supply will be substantial. Indeed, easier access to capital markets suggests that the current response might be greater than in the 1930s.

Although individuals and banks now play a smaller role in agricultural credit markets than in the 1930s, at the margin, reductions in credit from private lenders will still impose costs on some borrowers. In the 1930s, the costs borne by borrowers from reduced supplies of private credit following the enactment of state relief legislation were limited because federal credit agencies were expanding rapidly and pursuing "easy credit" programs. Although the share of federally held credit is larger now than in the 1930s, federal credit agencies have come under pressure to improve the profitability of their operations and there has been considerable interest in reducing their role (Barry 1985). Federal lenders are therefore not likely to provide as soft a cushion for borrowers as they did in the 1930s.

The analysis in this paper yields two other interesting results about the farm credit experience of the 1930s. First, in some instances, federal credit programs "crowded out" private lenders by providing low interest loans to borrowers who

were willing to borrow at the market rates. Second, the empirical results suggest that the state relief legislation of the 1930s actually reduced the demand for farm credit because of increased uncertainty to borrowers concerning the sanctity of future private loan agreements. The resulting reduction in demand for loans from this effect appears to have outweighed any increased demand resulting from features of the 1930s legislation that were favorable to borrowers.

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Utilization, Profitability, and the Adoption of Animal Draft Power in West Africa

William K. Jaeger and Peter J. Matlon

Farmers in West Africa's semi-arid tropics have been slow to adopt animal draft power to replace manual cultivation, defying the logic of conventional choice-of-technique analyses. This paper demonstrates that farmers can profitably adopt animal draft power when household characteristics and exogenous factors permit high utilization of animals and equipment. Empirical analysis of farm-level data indicates that low utilization is the key cause of low returns, and that a long learning period precedes achieving high utilization and benefits. Linear programming models are used to establish the importance of family size, access to land, and appropriate implements in achieving profitable adoption.

Key words: animal traction, learning curve, linear programming, semi-arid tropics, technology adoption, utilization.

Animal draft power presents a complex and important puzzle for agricultural development in the West African semi-arid tropics. Although animal traction has been promoted in most parts of the region since the beginning of the twentieth century, it is currently employed on less than 15% of total sown area (Spencer). Sustained adoption has occurred only in relatively limited geographic areas, such as the Sine Saloum region of Senegal, southern Mali, and southwestern Burkina Faso (Matlon). Elsewhere, initial adoption rates not only have been low, but early adopters have often abandoned the technique within three to five years (Sargent et al.). These patterns defy the logic of conventional choice-of-technique analyses. Although the West African semi-arid tropics are generally characterized as land abundant with seasonal labor shortages considered the primary production constraint (Norman, Newman, and Ouedraogo; Delgado and Ranade), farmers in most areas have not adopted a potentially labor-saving technique. This issue has generated considerable policy debate and a growing literature analyzing the principal adoption constraints.

Early studies examined factors limiting the supply of appropriate technologies and concluded that broad adoption was blocked by equipment inappropriately designed for African conditions, inadequate extension, and the absence of support services (Kline et al., Le Moigne). More recent field studies have shifted the debate to an examination of farm-level profitability and the demand for animal traction (Barrett et al., Lassiter, Delgado, Delgado and McIntire). The notable work by Delgado and McIntire concluded that oxen cultivation, in isolation from other components of improved technology, is not sufficiently profitable to compensate for the high opportunity cost of farm resources tied up in the technology. They used a conventional linear programming approach to examine farm-level demand for animal traction. Their model was synthesized from survey data from Burkina Faso (in a region where no animal traction was used) and Mali as well as from research station trials data from a variety of West African locations. Crawford and Lassiter, however, criticized that study (based on their own extensive field research in Burkina Faso) as having overestimated the labor costs of animal maintenance, for having underestimated supply-side constraints to traction adoption (extension, veterinary services, credit, equipment repair), and for using a single-period profit analysis to

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model a dynamic adoption process.

In this paper we present new data from four regions of Burkina Faso which demonstrate that animal traction can generate competitive returns to labor and capital. We describe the conditions under which farmers can use animal traction profitably, showing that high utilization of animals and equipment is crucial for profitable adoption. And we analyze the principal factors, both exogenous and endogenous to farm households, that can limit potential utilization and profitability of various animal traction components or equipment sets.

Characteristics of the Farming Systems

The present study draws on farm-level crop production data from six villages in four regions of Burkina Faso for the 1981 and 1982 seasons. Each region is represented by a sample of fifty to sixty households selected by a stratified random sampling procedure to arrive at approximately equal numbers of farm units employing animal traction and manual tillage techniques. Complete sets of input-output data were collected for each plot through weekly or biweekly interviews during the respective growing seasons. The study sites were selected to span the three major agroclimatic zones of West Africa's semi-arid tropics. They represent the dry Sahelian zone, the intermediate Sudanian zone, and the relatively humid northern Guinean zone (table 1). Land was relatively abundant in both the Sahel and north Guinean zones. Within the intermediate Sudanian zone, two sites were included to represent relatively high and relatively low population densities.[1] The length of the growing season, the reliability of rainfall, and the quality of the soils all improve moving from north (Sahelian zone) to south (north Guinean zone).

These regional conditions suggest that the northern Guinean region has the highest technical potential for gains from mechanized plowing (long season, heavier soils, crops responsive to intensification) and weeding (long season and land abundance provide opportunities for use). A highly elastic demand for cotton, produced in quantity only in that region, reinforces this expectation. The land-abundant Sudanian zone has considerable potential for mechanized weeding, but the densely populated Sudanian zone appears to have only moderate potential for either mechanized operation. The Sahelian zone has the least potential for gains from plowing (light soils) or for weeding (very short season limits opportunities for use).[2]

This assessment of the regional variation in potential for adoption is underscored by a recent comparative survey of the agronomic, demographic, and market conditions under which mechanized plowing has proven to be appropriate in Sub-Saharan Africa. Pingali, Bigot, and

[1] Data for the land-scarce and land-abundant Sudanian zones are from Nedogo and Diapangou, respectively. Those surveys were conducted by Purdue University's SAFGRAD project. The Sahel data comes from two villages near Djibo and the northern Guinean sample from two villages near Boromo, both collected as part of ICRISAT's West Africa Village Studies. The SAFGRAD data is for 1982, the ICRISAT data is for 1981 and 1982. See Jaeger and ICRISAT (1981) for details of the survey methodology.

[2] Although simple man–land ratios suggest that the Sahel has ample land for expansion, extremely low land productivity combined with considerable livestock pressure means that the effective arable land base is quite limited.

Table 1. Characteristics of the Survey Zones and Samples

	Sahelian Zone	Sudanian Zone: Land Scarce	Sudanian Zone: Land Abundant	North Guinean Zone
Rainfall, millimeters per year	300–500	500–700	500–700	700–1,000
Length of season, days	90–120	120–140	120–140	140–170
Rainfall variability	high	moderate	moderate	low
Soils	poor	moderate	poor	moderate
Population density, persons per square km.	25	15	50	55
Power source	oxen	donkey, oxen	donkey, oxen	oxen
Mechanized operations	plowing	plowing, weeding	weeding, line tracing	plowing
Years since adoption	2–3	7–9	7–9	4–5
Average hours of use	85	240	140	60

Binswanger cite five conditions that are closely associated with demand for plowing services: (*a*) high farming intensity induced either by demographic growth or market access, (*b*) crops with high yield response to improved soil preparation, (*c*) an important proportion of heavy soils which respond well to plowing but which are difficult to work manually, (*d*) a long growing season (or at least a long preparatory rainfall period) to reduce the labor conflict between plowing and timely planting,[3] and (*e*) market conditions which assure an elastic demand for increased production. Although Pingali, Bigot, and Binswanger did not examine similar factors that affect the adoption of traction weeding, access to land for farm expansion is the major environmental determinant (Sargent et al.).

Average Product and Use of Animal Draft Equipment

The differences across the four study zones provide only partial support for the hypothesized regional variation in draft power potential cited above. The characteristics of the zones and samples, including the level of utilization of animal traction, are shown in table 1. In table 2, simple cross-sectional comparisons of various measures of average productivity are made for each zone between equipped households and nonadopters. While not conclusive evidence, such comparisons of average factor use and productivity patterns highlight relationships that are explored in depth below.

Although average use rates for animals and equipment were empirically associated with differences in average factor productivity, neither corresponded closely to initial cross-zonal expectations based on agroclimatic considerations. For example, average use rates were highest in the land-scarce Sudanian village (240 hours per season) followed by the land-abundant Sudanian village (140 hours). As expected, equipped Sahelian farmers used their animals at low levels (85 hours). But the lowest use was observed among north Guinean farmers (60 hours) who had adopted only plowing and ridging equipment but not weeders.

When resource use and average products are compared between adopters and nonadopters, significant differences are observed. Returns to land and labor among adopters were largest in the land-abundant Sudanian village, where both plowing and weeding had been mechanized (table 2). In the land-scarce Sudanian village where plowing was not done, revenue and area per worker were also markedly greater among adopters compared to nonadopters, while returns to land was less.[4] In the north Guinean villages, differences in average factor productivity were similar to those in the land-abundant Sudanian village, though smaller and not significant for returns to land. The labor–land ratio is significantly lower among households equipped with animal traction in both Sahelian zones and in the north Guinean zone (1981), supporting the hypothesis that traction is a labor-saving technology which, under land surplus conditions, permits area expansion. But across zones only weak and inconsistent yield differences are observed when comparing adopters with nonadopters. Higher yields for several crops occur only in the land-abundant Sudanian village and in the north Guinean zone, where draft power is used primarily for plowing.

The absence of significant differences in average returns to either land or labor in the Sahel, and only modest differences in the north Guinean zone, undoubtedly reflect the low utilization of animals and equipment in these zones. The central question, then, is how to explain the causes of low utilization. In the most arid Sahelian zone, the short growing season (hence brief period for effective use) and low yields are sufficent factors for explaining the limited opportunities to use draft animals productively. Where the rainy season is longer, such as in the north Guinean zone, possible explanations include the provision of inappropriate or incomplete animal-drawn implement sets, farmer inexperience with traction techniques, small work force at the household level, or limited access to land.

An additional constraint on utilization is the lack of well-developed rental markets for draft animals in tillage operations. This is primarily because of the synchronous nature of these tasks whereby demand for rental services during limited periods coincides with owners' own use. As

[3] Farmers in the West African semi-arid tropics generally prefer to plant their predominantly full-season, photoperiod-sensitive varieties directly with the early rains with no soil preparation in order to maximize their growing period. Under these conditions, mechanized plowing actually increases labor requirements by introducing an additional operation early during the season.

[4] Yields in the land-scarce Sudanian village were generally lower among traction farmers who had mechanized only the weeding operation in an effort to expand cultivated areas. Because of the relatively high pressure on the land, expansion occurred primarily onto marginal soils and/or at the expense of a reduced fallow period. Moreover, labor input per hectare over the expanded area cultivated was significantly reduced by traction households, contributing further to lower yields but increasing output per unit of labor.

Table 2. Differences in Average Product between Animal Traction and Manual Tillage Households (in CFAF)

	Sahelian Zone				Sudanian Zones (1982)				Northern Guinean Zone			
	1981 Season		1982 Season		Land Scarce		Land Abundant		1981 Season		1982 Season	
	Manual Tillage (n = 31)	Animal Traction (n = 17)	Manual Tillage (n = 30)	Animal Traction (n = 17)	Manual Tillage (n = 24)	Animal Traction (n = 36)	Manual Tillage (n = 11)	Animal Traction (n = 48)	Manual Tillage (n = 15)	Animal Traction (n = 10)	Manual Tillage (n = 34)	Animal Traction (n = 24)
Revenue per hectare	36,000	30,700[a]	13,400	15,100	24,200	20,600*	22,200	26,300*	28,100	35,100	27,900	29,800
	(2,233)	(2,481)	(925)	(1,817)	(1,947)	(837)	(3,113)	(929)	(1,934)	(4,222)	(5,293)	(2,887)
Revenue per hour of labor	129	107	60	58	50	63***	35	62***	68	103**	60	85*
	(11)	(12)	(5)	(8)	(3.5)	(3.3)	(5.2)	(3.2)	(6.4)	(14)	(7)	(14)
Labor to land ratio (hrs/ha)	309	319[b]	240	311	507	344***	677	465***	437	353**	490	470
	(19)	(28)	(15)	(42)	(138)	(97)	(49)	(23)	(28)	(19)	(49)	(50)
Area per worker (ha)	1.12	1.45	1.14	0.97	0.97	1.27***	0.93	1.11	1.19	1.28	0.79	0.9
	(.07)	(.32)	(.07)	(.10)	(.05)	(.07)	(.12)	(.06)	(.13)	(.16)	(.08)	(.11)
Yields (kg/ha):												
Millet	490	390**	180	200	370	360	400	500**	410	520	720	420
	(31)	(31)	(13)	(28)	(28)	(21)	(37)	(17)	(67)	(158)	(352)	(80)
White sorghum	490	1,080	210	500	550	360*	230	530***	560	480	320	520*
	(97)	(518)	(319)	(453)	(88)	(36)	(64)	(55)	(72)	(72)	(59)	(97)
Maize	500	370	240	50[c]	1,150	990	1,430	1,810*	2,540	3,750	1,710	1,750
	(103)	(72)	(142)	(13)	(219)	(120)	(171)	(109)	(394)	(1,014)	(466)	(313)
Peanuts	1,130	740	300	120[c]	540	470	350	570***	410	370	540	480
	(447)	(232)	(129)	(16)	(73)	(57)	(33)	(40)	(93)	(123)	(111)	(131)
Cotton									640	1,170**	940	1,030
									(84)	(198)	(206)	(206)

[a] Standard errors are in parentheses, significance levels are: * = .10; ** = .05; *** = .01. Significance tests are between group means of animal traction and manual tillage households.
[b] Includes hired labor and invited work parties.
[c] Small sample.

a result, investments and recurrent costs of maintaining draft animals year-round must be offset during the short period when they are put into productive own-farm use.

Labor Savings—Substitution of Capital for Labor

Comparing farming systems where traction plowing replaces manual soil preparation, the labor-saving benefits of mechanization are unchallenged. However, whether animal traction equipment saves labor in weeding operations remains a controversial issue. Delgado and McIntire exclude a traction weeding activity from their model on the basis of the low propensity of farmers to adopt animal-drawn weeders observed in the past in many parts of the region. Citing evidence from Senegal, they argued further that traction plowing alone actually increases the labor required for weed control. However, based on a detailed review of all available farm surveys conducted in the francophone parts of the region, Sargent et al. reported labor savings in traction weeding of up to 60%. They attributed the low adoption of weeders observed in some West African locations to the still infrequent practice of line planting and to the difficulties experienced by early adopters in guiding untrained animals through standing crops. In support of the latter argument, Barrett et al. showed that the propensity to use traction weeding equipment in the eastern region of Burkina Faso increases directly with years of traction experience. Moreover, the ubiquitous employment of traction weeding systems in other semi-arid zones of the world where traction has a longer history, most notably in India, further supports the labor-saving hypothesis.

In order to test for labor-saving effects in the survey data, gross farm revenue was regressed on physical units of labor and nonlabor inputs and estimated rates of technical substitution of manual for animal traction labor. Characteristics of agricultural production in areas such as Burkina Faso present special problems for production function analysis. Thin rural labor markets prevent using wage rates for reliable labor cost comparisons by season and type. Capital inputs are insignificant except for animal traction and fertilizer, which are handled separately. And land abundant agricultural systems with no land market pose problems for valuing widely varying qualities of land. Aside from clearing costs and travel time to and from fields, the costs of bush land are negligible. While some variation occurs across crops, labor and land are used at fairly constant proportions; and, as a costless input, land can be excluded from the functional form (it is assumed to be used at the level that maximizes the returns to the costly factors of production). Only in the north Guinean region, where improving soil fertility can have substantial gains due to the importance of cotton, is substitutability between land and labor, or capital, an interesting issue.

As a result of the extremely low levels of purchased inputs as well as limited data on opportunity costs for household labor, gross rather than net farm revenue has been used in the econometric analyses. The investment costs and profitability of animal traction are considered later.

We used the following linear separable form:

$$\begin{aligned} \textit{TOTAL FARM CROP REVENUE (FCFA)} = {} & b_0 + b_1\, \textit{LABOR HOURS} \text{ (excludes harvest)} \\ & + b_2\, \textit{DRAFT TEAM HOURS} \\ & + b_3\, \textit{FERTILIZER} \text{ (kilograms)} \\ & + b_4\, \textit{MANURE} \text{ (kilograms)} + \epsilon. \end{aligned}$$

The implicit assumption is that human and animal traction labor are substitutable at a constant rate, and that returns to scale are constant. A standard Cobb-Douglas production function was estimated for all villages, and the hypothesis of constant returns to scale was retained. Most variation between households is caused by differences in family size and cultivated area, both of which covary closely.

Results in table 3 indicate large potential labor savings, with marginal rates of technical substitution (defined as the ratios of the estimated coefficients) between draft animal power and human labor significantly greater than one in all zones. The ratios are quite high where both coefficients are significant—10.4 in the Sahel, and 9.8 and 5.3 in the land-abundant and land-scarce Sudanian villages, respectively. The particularly high coefficients in the north Guinean zone probably reflect the exclusion of explanatory variables from the estimation, in particular the residual effects of past investments in soil fertility or differences in crop mix and soil type.

Table 3. Aggregated Linear Separable Regression Model

Dependent Variable = Gross Value of Farm Production (CFAF)

	Sahelian Zone		Sudanian Zone		Northern Guinean Zone	
	1981 (n = 48)	1982 (n = 47)	Land Scarce (n = 60)	Land Abundant (n = 59)	1981 (n = 25)	1982 (n = 58)
Constant	2922	4321[a]**	1188	−1348	692	4767
	(0.7)	(2.3)	(0.7)	(−.6)	(0.1)	(1.1)
Nonharvest labor hours	84***	29**	43***	46***	41*	27
	(4.9)	(2.6)	(7.7)	(6.9)	(1.9)	(1.3)
Draft team hours	874***	86	229***	453***	1271	2109***
	(4.5)	(0.5)	(5.8)	(4.5)	(1.3)	(2.8)
Fertilizer (kg)					1037***	604***
					(4.5)	(3.7)
Manure (kg)	9	2			0	−6*
	(1.6)	(1.0)			(.01)	(1.7)
MRTS[b]	10.4	3.0	5.3	9.8	31	78
R-square	0.72	0.18	0.57	0.53	0.67	0.36
F-value	38.3***	3.2**	38.6***	31.9***	10***	7.5***

[a] To correct for heteroscedasticity, weighted least squares was applied dividing each observation by the number of residents in the household. T-values are in parentheses; significance levels are: * = .10, ** = .05, *** = .01.
[b] Marginal rate of technical substitution between animal draft team labor and manual labor.

Nevertheless, the coefficients are consistent with the expected high potential of traction tillage in that zone. Overall, these estimates provide persuasive evidence that, with two persons guiding a single donkey or even three persons required to guide a team of oxen, human labor is substantially more physically productive with traction equipment than when cultivating by hand.

The Learning Curve

High rates of technical substitution suggest adequate incentives for much greater equipment utilization than was observed in the survey. Previous studies, however, have suggested that a slow learning process in mastering animal traction techniques may lead to inefficient and low use immediately after adoption (Barrett et al., Lassiter, Sargent et al.). This in turn makes adoption of animal traction less attractive to farmers because of delayed benefits and the long payback period on their investment.

The learning curve is empirically estimated from the survey data using the following model:

$$TOTAL\ HOURS\ OF\ USE = b_0 + b_1\ YEARS\ SINCE\ ADOPTION + b_2\ (YEARS\ SINCE\ ADOPTION)^2 + \epsilon.$$

The length of time since initial adoption explains between 20% and 60% of variation in hours of use. The regression results (table 4) showed that the response curve estimated for the northern Guinea zone leveled off sooner than did those for the Sudanian zones. This reflects an "upper bound" on utilization for the plow and ridger in the north Guinean zone that was more limiting than the potentially higher utilization for farm-

Table 4. Estimated Relationship between Years of Experience and Hours of use of Animal Traction

Dependent Variable: Total Hours of Use

	Sudanian Zone		Northern Guinean Zone	
	Land Scarce (n = 60)	Land Abundant (n = 59)	1981 (n = 25)	1982 (n = 58)
Intercept	41.3[a]	24.9	7.1	−46.1
	(59)	(42)	(12)	(38)
Years since adoption	40.4***	19.7**	17.4**	40.1***
	(14)	(9)	(6)	(12)
Years since adoption squared	−1.4*	−0.5	−1.2*	−2.4***
	(.7)	(.4)	(.5)	(.8)
R-squared	0.3	0.2	0.6	0.3
F-value	7.4	6.4	6.0	5.1

Note: Nearly all traction farmers in our Sahelian sample had used draft power for the same number of years (three in 1981 and four in 1982), making estimation of this relationship impossible.
[a] Standard errors are in parentheses; significance levels are: * = .10, ** = .05, *** = .01.

ers who employ weeders, or weeders and plows, as among farmers in the Sudanian villages.

Direct estimation of the relationship between total farm product and experience would be extremely difficult because of high variability in the large number of factors affecting a household's production in a particular year. Area cultivated, however, is a more stable and direct indicator of the hypothesized effect of experience. In the two Sudanian zones where animal-drawn weeding was practiced among traction households, a quadratic regression equation was estimated between years since adoption, family size and composition, and area cultivated:

$$\begin{aligned} AREA\ CULTIVATED = b_0 &+ b_1\ WORKING\ MEN + B_2\ WORKING\ WOMEN \\ &+ b_3\ WORKING\ CHILDREN + b_4\ YEARS\ OF\ EXPERIENCE \\ &+ b_5\ (YEARS\ OF\ EXPERIENCE)^2 \\ &+ b_6\ ADDITIONAL\ DRAFT\ TEAMS\ OWNED + \epsilon. \end{aligned}$$

The results confirm a strong and statistically significant relationship (table 5, fig. 1), suggesting that after five or six years of experience, farmers can achieve area increases of two or more hectares.[5] The relationship between experience and farm size mirrors the pattern found between experience and utilization. Stated simply, these results indicate that new adopters do not benefit from animal traction primarily because they do not use it.

Table 5. Estimated Relationship between Experience with Animal Traction and Area Cultivated

Dependent Variable = Farm Size (hectares)	Sudanian Zones	
	Land Scarce	Land Abundant
Intercept	1.73 (1.8)	0.015 (2.5)
Working men	0.35** (.24)	0.56* (.44)
Working women	0.76*** (.22)	1.29*** (.245)
Working children	0.48** (.25)	0.44** (.242)
Years experience with animal traction	0.40** (.17)	0.41** (.23)
Years experience, squared	−0.017* (.01)	−0.023* (.015)
Number of additional household draft teams[b]	1.60** (.67)	0.71 (.61)
R-square	0.70	0.64
F-value	20	15

[a] Standard errors are in parentheses. Significance levels are: * = .10, ** = .05, *** = .01.
[b] Several households possessed more than one donkey, pair of oxen, or a combination of the two.

A Linear Programming Model of the Farm

If animal traction is labor augmenting and some farmers are able to achieve high utilization and large benefits, why are adoption rates so low? The high initial cost and long learning period may prohibit some farmers from adopting because of poorly functioning credit markets, but our analysis suggests that other factors are involved. A linear programming model of the family farm was constructed to examine the effects of farm size (number of workers), restricted access to land, different equipment components, and low utilization of draft animals on the profitability of animal traction. Because the analysis compared manual, donkey, and oxen systems, technical coefficients were derived from the land-abundant Sudanian village, the only site where the number of observations permits specification of all three tillage systems. Up to fifteen production techniques were included for each major crop. These techniques were distinguished by differences in timing and level of labor inputs for planting, weeding, and plowing, each with its associated yield effects. All technical coefficients were derived from survey data.

The model employed a profit-maximizing objective function, augmented by a target MOTAD configuration that requires household subsistence needs to be satisfied with a specific

[5] This time-series inference from cross-sectional data must be qualified. If early adopters tend to be better farmers, then the inference may be incorrect. But this formulation controls for the possibility that use and area cultivated might be greater among more experienced households simply because early adopters may have larger family work forces. With family size and composition variables included, the regression results reject the hypothesis that the observed phenomenon simply results from large households having been the early adopters.

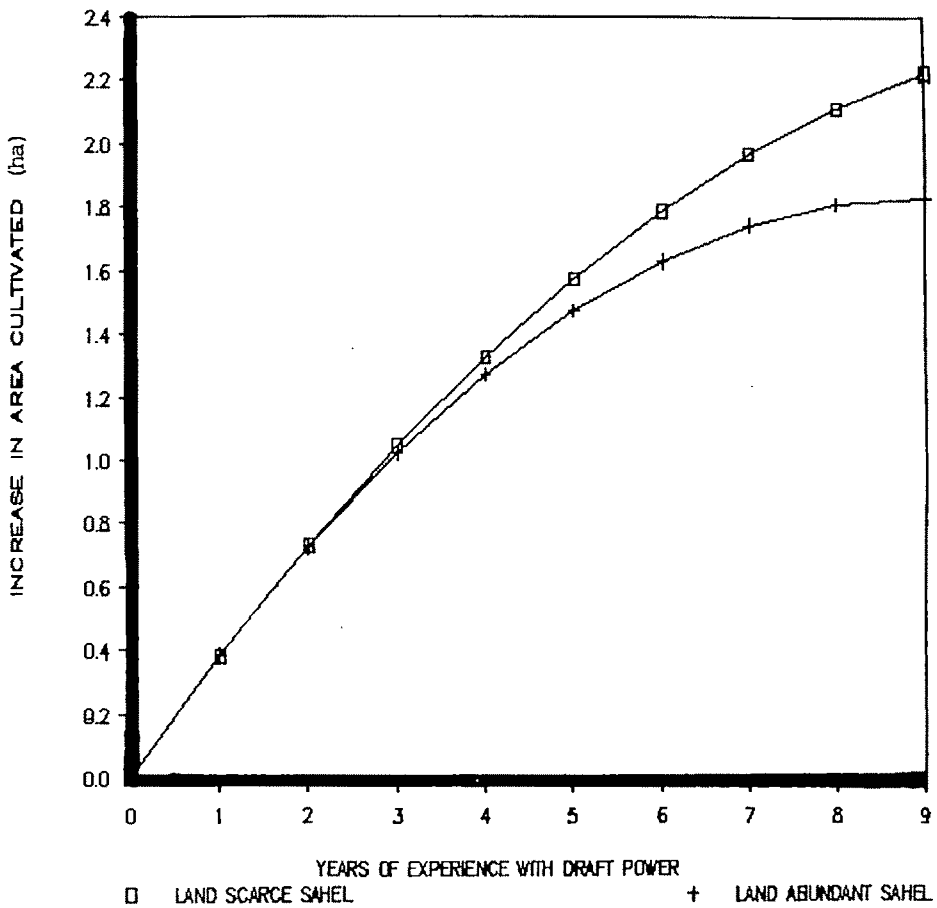

Figure 1. Estimated learning curve: regression results

degree of certainty.[6] Labor was limited to the family labor pool because of the absence of a significant, reliable rural labor market. The model allowed forty, thirty, and twenty-five hours per week for men, women, and children, respectively, and included consideration of household members' obligations for other domestic tasks as well as travel time to and from fields. The model also permitted substitution of labor types by age and sex, and with draft animals, at task-specific rates of substitution which reflect differences in performance derived from the survey data using regression estimates not presented here (Jaeger).

Three types of land were specified to reflect actual data on land availability, cropping patterns, and productivity in the survey village. Early planting and plowing were restricted in accordance with the likelihood of having sufficient moisture in the soil to perform those tasks. These latter parameters were derived from twenty-five years of secondary rainfall data combined with an analysis of the relationship between rainfall amounts and the number of succeeding days during which these tasks can be performed, based on the survey data.

Animal traction was introduced in the model

[6] Most farmers in semi-arid West Africa allocate resources first to assure their own subsistance requirements before maximizing income from marketed production. This behavior is incorporated into the farm model with a targeted MOTAD formulation (Hazell, Tauer) in which subsistance consumption requirements (defined in terms of cereal per adult male equivalent) are assured at an 80% probability with the constraints:

$$\sum_{i=1}^{n} C_{hi}X_i - S + Y_h \geqq 0 \; for \; h = 1, \ldots, 20, \text{ and}$$

$$\sum_{h=1}^{20} Y_h \leqq \lambda * S$$

where C_{hi} is a matrix of yields associated with the i cereal production activities for h states of nature, Y is vector of negative deviations from the target subsistance level s, λ is the total expected negative deviations from the target level over the h states of nature, and n is the number of crop production activities (Jaeger).

as an integer variable, making it available for use while imposing the year-round cash and labor costs of animal tending. Draft animal use, however, was determined endogenously, with the model employing animal traction at efficient levels consistent with the available household labor necessary for care and field work. By including animal traction as an integer variable, the modeled household was forced to own, rather than rent, the specific package of animals and implements, consistent with the near absence of rental markets.

Results

The basic solution of the farm model was consistent with observed farmer behavior (table 6). The ox plow used alone generated no acreage expansion, and draft team use was limited to only 60 hours. Very small yield increases resulted from ox plowing; but the cropping pattern shifted slightly to maize and bambara nuts, which are more responsive to deep soil preparation. Plowing did not enter the solution for other crop activities where the yield response is marginal, especially since the model realistically forced plowing to delay planting and to exacerbate the weeding labor bottleneck. By contrast, using weeding implements alone resulted in the cultivation of an additional four hectares, most sown with peanuts. Draft animal use increased to 300 hours.

When the model permitted use of the plow together with the weeder, net income doubled compared to the manual tillage solution and equipment use was maximized at over 400 hours. Traction plowing resulted in yield increases and

Table 6. Results of Various Specifications of a Representative Farm Model (household with seven active members) Compared to Field Observations

	Observed Sample Mean, Land Abundant Sudanian Zone[a]	Model Results					
		Manual Tillage	Ox Plow	Ox Weeder	Complete Ox Traction	Donkey Weeder	Complete Donkey Traction
Value of total farm production (thousand CFAF):	185	192	194	329	404	351	373
Area cultivated (ha):							
Millet	5.7	5.2	4.8	6.9	6.7	6.6	5.2
Sorghum	.5	.8	.7	1.0	1.0	1.0	.8
Maize	.3	.4	.5	0	.4	.1	.4
Peanuts	.3	.4	.4	3.1	3.4	3.5	4.3
Bambara nuts	.1	.2	.6	0	1.1	0	.7
Soybeans	.1	0	0	.1	0	.1	.2
Total	7.0	7.0	7.0	11.1	12.6	11.3	11.6
Labor use							
Hours per man	641	538	397	488	443	540	469
Hours per woman	437	260	277	313	274	295	232
Hours per child	350	128	87	222	256	202	218
Draft animal use (hours):							
Plowing	83[a]		60		114		126
1st weeding	15			169	190	198	166
2nd weed./ridging	38			132	109	105	84
Total	136		60	301	413	303	376
Shadow price for men's labor (CFA/hour):							
June 14–20		180	0	0	0	0	0
June 21–27		280	117	260	240	240	190
June 28–July		370	30	290	320	290	360
July 5–11		200	390	260	390	260	350
July 12–18		320	110	50	114	40	50
July 19–25		150	190	150	290	150	190
July 26–Aug.		620	715	210	310	210	250
Aug. 2–8		0	140	0	0	0	0
Aug. 9–15		40	120	40	0	50	0

[a] Observed sample means for entire survey group. Means for draft animal use are derived from totals for all households possessing traction equipment.

expanded acreage for the most responsive crops. Normally, plowing would have resulted in delayed planting and increased labor requirements during the peak weeding period when late planting continued. However, weeding implements overcame this bottleneck because the farmer could not only preserve the positive yield effects but also increase cultivated area. The predicted cropping pattern and levels and shifts in family labor use were quite close to those actually observed. These results support the hypothesis that the scarcity of weeding equipment in the north Guinean zone was a key element in explaining the surprisingly low use and factor productivity observed in that zone.

Sensitivity Analyses

By parametrically varying key constraints in the model, we also traced the effects of changes in utilization, size of farm work force, and land scarcity on cropping patterns and farm income. Hours of usage were restricted to various levels in order to simulate the effect of underutilization and the results were plotted as a curve relating utilization to increases in farm income (fig. 2). The model predicted that draft animal use could increase beyond the average levels observed, but not beyond the range observed in the survey data. The results further underscored the crucial importance of attaining high levels of use to be profitable.

Similarly, varying the number of family workers indicated that farm revenues were positively associated with family size (fig. 3). Smaller farms were disadvantaged because the labor required to maintain the draft animals is a larger share of total farm labor, and the small area that can be planted limits utilization of the draft animals for weeding and plowing to lower levels.[7]

[7] The mean number of active household members for rural families in Burkina is about seven and for all survey villages mean active family size for the manual tillage group was approximately half that of households using draft systems. Indeed, a common characteristic of nearly all animal traction studies in West Africa is that the mean family size among the animal traction households is nearly twice that of hand tillage units.

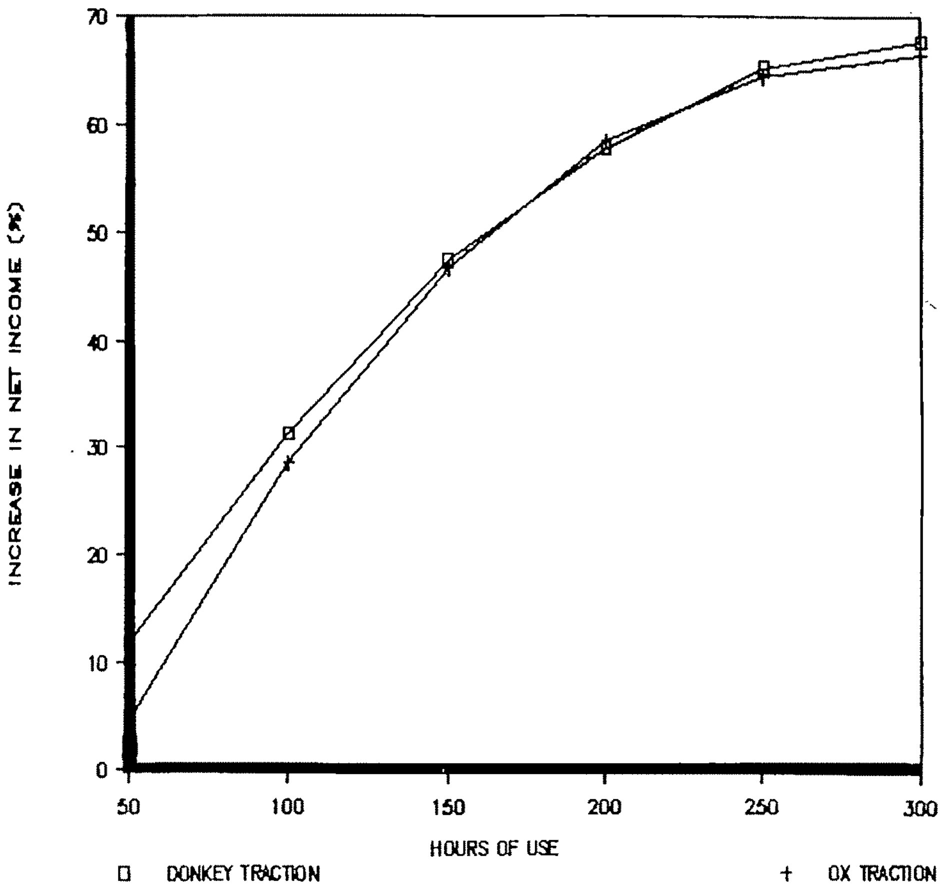

Figure 2. Farm income and traction utilization: LP model results

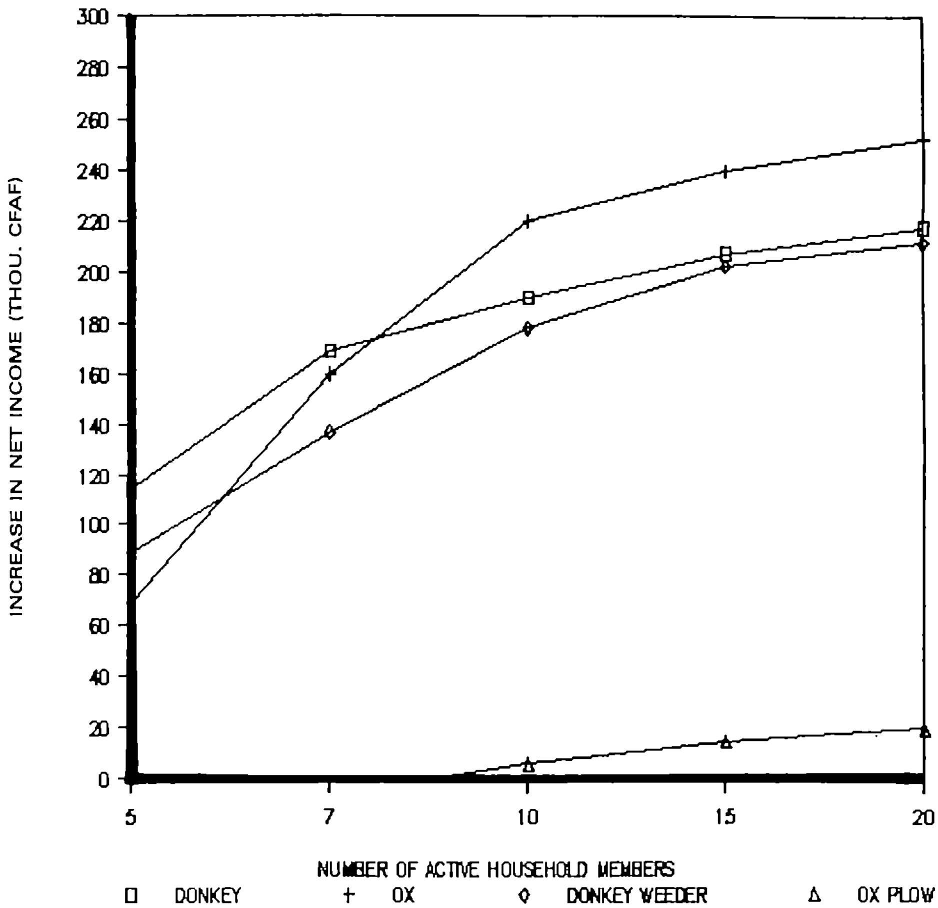

Figure 3. Economies of farm size and animal traction

Not all farmers in these regions have access to additional land or to land of sufficient quality to profit from extensification with animal traction. When area expansion was restricted in the model, the benefits of animal traction were substantially reduced. Although a small increase in yields with animal traction plowing permitted a marginal increase in gross farm income above that for manual tillage, the results underline the crucial importance of access to land to ensure profitability in these farming systems.

Return on Farmers' Investment

In a series of model runs, internal rates of return from eight-year partial budget streams were computed under several sets of assumptions about the rate of increase in utilization and final use levels. Costs of equipment, maintenance, depreciation, and expected losses due to risk of draft animal mortality were based on survey data.

The model predicted that the initial investment in the full equipment set is not recouped until the fifth year (using a 10% discount rate) when full benefits are also achieved. When partial budget streams were computed using benefits observed in the surveys, the resulting internal rates of return were 26% for ox traction and 35% for donkey traction; these differentials reflect the lower investment costs and comparable benefit streams for donkey versus oxen traction. Using the income gains predicted by the model but restricting utilization and learning to be consistent with observations, rates of return of 25% and 41% were estimated for oxen and donkey traction, respectively. When the learning period was cut by half, or when levels of utilization were increased by 50%, rates of return exceeded 40% for oxen traction and 60% for donkey traction.

Although these returns compare favorably with commercial banking rates, in regions where rural capital markets impose high risk premiums, interest rates can easily exceed these levels. Rates of return of between 35% and 70% likely are

inadequate for near-subsistence farmers for whom assets serve as the major means of covering production risks and meeting family emergencies. Households that have accumulated assets beyond that required to serve as crop insurance will perceive lower opportunity costs of capital and thus may be more willing to invest in animal traction.

The relative importance of these factors differs by region. In the Sahel, where production risks are higher, crop insurance substitutes are more important than, for example, in the north Guinean zone where higher and more assured rainfall and yields make intertemporal variation in production smaller and less critical. In short, the effect is to increase the implicit cost of capital in zones of higher risk which further constrains investment in traction systems.

Previous Work Reconsidered: The Harvest "Constraint"

The analysis presented here is consistent with most prior literature and field surveys, which generally found evidence of area expansion effects with the introduction of animal traction but only limited support for yield effects (Barrett et al., Sargent et al., Delgado and McIntire, Lassiter). Cases where evidence of achieved benefits was limited were usually associated with inexperienced farmers. In the Barrett et al. and Lassiter studies, for example, over half of the farmers in the sample had less than three years of experience and a similar share used their draft animals less than fifty hours during the year. Previous studies also gave insufficient weight to the distinction between plowing and weeding implements in determining the kinds of expected benefits.

However, the important work by Delgado, and later by Delgado and McIntire, differs from the main body of work on this subject in several respects, some of which were mentioned above. But their conclusions derive primarily from the assumptions made about the yield effects and the associated harvest labor requirements resulting from adoption of animal traction. Delgado's model relies upon research station trials to assume large increases in yield (120% for millet and sorghum, 190% for groundnuts, 230% for cotton). Harvest labor requirements are increased proportionally, and these labor requirements are concentrated in a single two-week period.

As a result of these assumptions, labor during this two-week period is severely constrained (becoming the only binding labor constraint) and is the pivotal determinant of his results in which oxen traction was unprofitable.[8]

This severe harvest labor constraint built into the Delgado model forces total area cultivated in the animal traction solution to be reduced by two-thirds and leaves more than half of available household labor idle throughout the entire cropping season. This result implies that, because of the anticipated crop losses from pest damage caused by delayed crop removal, farmers would stop planting when they judge that the expected harvest would exceed their ability to harvest it promptly. Such perceptions and behavior were not observed in any of the four systems examined in the present study, and no evidence of reductions in farm size resulting from the adoption of animal traction is found in other farm-level studies conducted in the region.

Concluding Comments

This study demonstrates that particular components of draft animal tillage systems can be profitably adopted by farmers in the West African semi-arid tropics when factors internal and external to the household production unit permit high utilization of animals and equipment. The conclusions follow from three central findings: first, animal draft power is significantly labor saving when used in appropriate tillage operations; second, high use of animals and equipment is crucial to achieving competitive returns on investment in them; and third, the capacity of farmers to use animal traction at high rates is a function of agroclimatic factors, equipment types, farmers' experience with the technology, and farm size.

The results confirm that animal-drawn weeding equipment can significantly raise labor productivity during the most critical labor bottleneck period. Across zones, the minimum marginal rate of technical substitution between manual and traction labor was greater than five. This result indicates high use potential for weeding equipment in those zones where land availabilities permit area expansion and where labor in other operations is not limiting. The use of both plowing and weeding implements offers considerable potential complementarity in re-

[8] Our survey data indicate that harvest lasts 3 to 8 weeks on major fields.

gions where land is available and the length of the growing season is sufficient.

The potential gains from animal draft power also vary by region depending on a broad set of agroclimatic and economic factors. The short rainfall season and light soils of the Sahel zone strictly limit potential utilization and profitability. The potential in the northern Guinean zone is greater because of a longer growing season, deeper soils, and the presence of an important cash crop, cotton.

Satisfying these exogenous regional conditions for a given equipment package, however, does not assure high utilization for individual production units. Animal traction systems are lumpy and display important economies of scale. Thin and inefficient factor markets mean that characteristics of individual production units are very important in determining which households can adopt traction systems profitably. Because equipment rental opportunities are tightly constrained by the synchronous nature of tillage operations, investment costs must be spread over a large operated area in order to achieve profitable use levels. A large household labor force is also advantageous for spreading the animal-tending costs over more individuals and for conducting nonmechanized farm operations on an expanded area. Initial capital requirements and returns to animals and equipment which are only marginally competitive with the opportunity cost of capital also tend to bias adoption to households with more abundant capital. And in regions where low and erratic rainfall makes agriculture riskier, the opportunity cost of a household's accumulated assets may be even higher because of their important role as a form of insurance.

Animal traction requires not only a large capital investment for farming households but also a major reallocation of family labor and the development of new skills. Both processes can delay achieving full utilization and benefits by up to seven years after initial adoption. During this period adopters can face a severe cash flow problem which, if exacerbated by unfavorable weather and poor harvests, can force asset-poor households into financial loss and divestment.

The implications of these results for mechanization policy are clear. Given the wide diversity which characterizes West Africa, equipment packages should be designed and targeted only to areas where agroclimatic conditions and available land permit high and profitable utilization. Further targeting of extension assistance within those areas to larger and better endowed farmers could improve adoption success. Such targeting would favor already privileged producers; that is, households located in higher potential zones and those more favorably endowed with land and other farm-level resources. But to promote adoption among farmers in marginal areas (to advance equity) and among those who lack the complementary resources needed to fully utilize the equipment and animals would only result in burdening them with untenable investments.

Finally, policy makers should recognize that continued population growth into the next century will eventually preclude sizable productivity gains solely from the labor saving, area expansion benefits of animal draft which currently predominate. As land becomes more scarce, technical change toward more intensive and sustainable yield-augmenting technologies will become increasingly crucial. Growth in the size and income of the nonfarm sector is likely to raise agricultural prices, further improving the economics of more intensive technologies. Where agroclimatic conditions permit high utilization, mechanized plowing will derive greater importance as deep tillage becomes an essential farm operation for those intensive systems.

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Integration of Spatial Markets

Merle D. Faminow and Bruce L. Benson

Studies of spatial market integration draw their implications from a theory which assumes that there are no intraregional transport costs. An alternative theory is offered, based on the assumptions that buyers and sellers are spatially dispersed and intraregional transport costs are significant. This implies that the market is a linked oligopoly (or oligopsony) and that market integration tests are tests of alternative oligopoly price formation processes. For example, collusive basing-point pricing produces results typically assumed to imply efficiently integrated markets, while competitive FOB pricing does not. The theoretical implications are illustrated with an analysis of hog prices in Canada.

Key words: Canadian hog prices, spatial market integration, spatial oligopoly.

Spatial price relationships for agricultural and food commodities have been widely used to indicate market performance. For example, two generally accepted principles thought to underlie regional price differences are (Tomek and Robinson, p. 151): (*a*) price differences between any two regions (or markets) that trade with each other will just equal transfer costs; (*b*) price differences between any two regions (or markets) that do not engage in trade with each other will be less than or equal to transfer costs.

The seminal book by Takayama and Judge provides the necessary theoretical justification for these principles, given certain explicit assumptions. Of particular interest here is the assumption that all transactions within a region occur at a point; that is, no intraregional transportation costs apply (effectively, all buyers and sellers are located at a single point). Although some applied studies of spatial market integration directly acknowledge the importance of the Takayama and Judge formulation (e.g., Ravallion), others do not (Harriss, Jones).

A direct application of the two principles listed above is to test statistically whether price differences between regions (markets) are greater than, less than, or equal to transfer costs. Prices can also be compared to those which might exist under a "perfect" economic system. In practice, this has been done by solving a Takayama-Judge spatial equilibrium model for theoretical prices or price differences between regions (Leath and Blakley).[1]

A less direct application of the Takayama-Judge model, employing price responses between various regions or markets, has also been developed. If two sites trade with each other, price changes in one should lead to identical price responses in the other. Thus, Monke and Petzel (p. 482) define integrated markets as "markets in which prices of differentiated products do not behave independently." In the case of spatial markets, identical products are assumed to be differentiated by location, and statistical tests of interdependence between prices at different locations are employed to indicate the degree of market integration. Bivariate correlations of price series between pairs of markets that approach a value of 1.0 infer market integration (Jones, Stigler and Sherwin, Neal). Taken together, available studies using price correlation comparisons suggest that market integration is often quite low, although the markets appear to operate competitively. Problems with this statistical test have led researchers to advocate the

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[1] Although it is widely known that a spatial equilibrium model can be solved to compute equilibrium price or price differences between regions, this is not often done. One problem is that actual transfer costs are determined in a market with supply and demand conditions, but a supply/demand component for transfer services is generally not included as one part of an empirical spatial equilibrium model (Seaver, p. 1370). In addition, the findings of Wallace suggest that actual and predicted price levels and differences are not closely correlated when a linear programming model is used to determine "predicted" prices.

use of statistical procedures that include lagged responses and/or consideration of normal seasonal fluctuations (Blyn, Harriss, Ravallion, Delgado).

In this paper we suggest a revised structural view of intermarket price interdependence by realistically assuming that buyers and sellers are both spatially dispersed and intraregional transportation costs exist—an obvious characteristic of agricultural and food markets. This approach alters theoretical expectations of price relationships in spatial markets and, therefore, alters the interpretation of market integration tests proposed by Ravallion. The next section examines relevant aspects of spatial price theory. This is followed by a section which delineates the Ravallion tests and suggests possible modifications in their interpretation. An application is then made to hog prices in Canada.

Price Relationships in a Spatial Market

A large literature deals with spatial competition in agricultural and food markets. The least-cost approach, based upon the location theory of Weber and Isard, examines the trade-offs between the costs of assembling inputs and distributing outputs. The relative costs of nontransferable inputs across potential sites, the cost of transporting transferable inputs to possible locations, and the cost of shipping finished products from these sites to markets are of primary concern. Spatial equilibrium models, based on linear or quadratic programming, have this theoretic base (e.g., Takayama and Judge, chap. 3).

Central to the solution of these models, and therefore predictions regarding price equilibrium conditions, is the assumption that a geographic area can be partitioned into a discrete number of regions in which all intraregional transfer costs are zero. Intraregional competition and trade can be characterized by the perfect competition model, and regional boundaries are assumed fixed.

A second spatial approach emphasizes locational interdependence, based upon the early writings of Hotelling and Smithies (e.g., Greenhut 1971). In markets where sellers and buyers are spatially distributed, transfer costs affect the net price received or paid. In food markets, consumers generally consider only those retailers who are located nearby even though many more retail outlets may exist in the economic market (Benson and Faminow). Similarly, in agricultural product markets, even when large numbers of buyers are located across a geographic area, farmers typically compare the prices in several proximate locations because of intraregional transport costs. That is, farmers differentiate between buyers on the basis of location. This suggests a second characteristic of spatial competition. Even when many sellers (buyers) are located in a geographic area, each considers only nearest rivals as major competitors, so linked oligopolistic (oligopsonistic) competition characterizes food retail (agricultural product) markets where expected pricing responses of rivals—conjectural variations—also determine pricing policy. Thus, spatial markets where both buyers and sellers are dispersed and transport costs are significant should not be characterized as perfectly competitive (Greenhut 1971). Furthermore, regional boundaries become a function of relative prices and do not remain fixed as prices change.

Market integration, that is, the process by which price interdependence occurs, can be directly deduced by developing a model of spatial oligopolistic (or oligopsonistic) competition. This model allows illustration of price reaction functions which form the theoretical basis for price interdependence (i.e., integration) in spatial markets.

In keeping with the spatial literature, the model given below is couched in terms of a few firms selling to spatially dispersed consumers located on a linear market (oligopoly). The theoretical example developed here will assume three spatially separated sellers, X, Y, and Z in figure 1, with consumers evenly distributed between X and Z. However, the results generalize to much larger numbers of sellers located at either the same sites (X, Y, and Z) or at numerous other sites, to unevenly distributed buyers and/or sellers, and to a two-dimensional space, although with increased mathematical complexity (magnitudes change but not comparative statics). In addition, they easily generalize to a market with relatively few buyers (e.g., at X, Y, and Z) and large numbers of spatially distributed sellers—oligopsony rather than oligopoly. This is an important point because some stages of the vertically linked series of markets which transform agricultural products into consumer goods (e.g., producer to processor markets) involve a few relatively widely dispersed buyers and much more numerous and more ubiquitously located sellers. Other stages, such as food retailing, readily lend themselves to spatial oligopoly modeling, however (Benson and Faminow). Therefore, the theoretical pre-

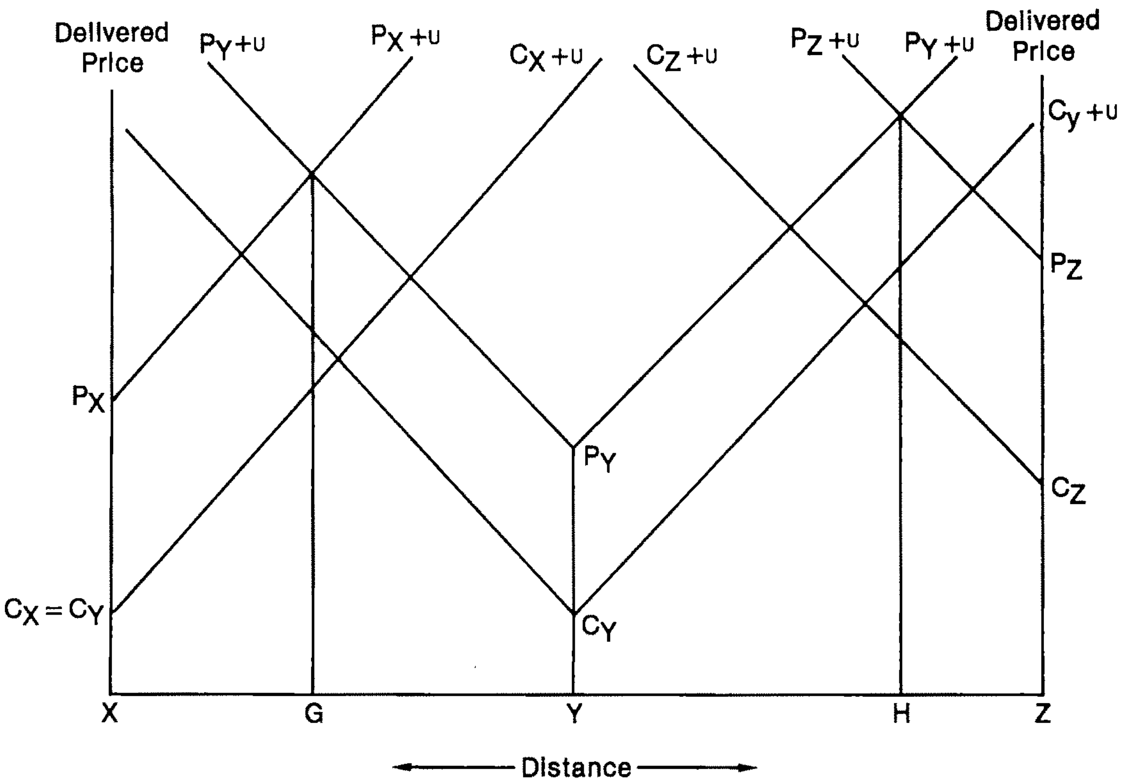

Figure 1. FOB pricing

sentation focuses on oligopoly in order to emphasize the generality of the market interdependence implications of spatial competition and to establish clearly these implications in the context of an extensive existing literature.

Spatial Competition under FOB Pricing

Assume identical consumers are evenly and continuously distributed between X and Z in figure 1. Let demand at each buying point for the physically homogenous product be of the form

(1) $$\bar{P} = a - (b/v)\, q^{v},$$

where $\bar{P}$ represents delivered price, q denotes quantity demanded, a and b are positive constants, and v is a constant parameter which can be positive or negative but greater than -1.[2] Delivered price, $\bar{P}$, consists of the price actually set by a firm, p, and transport costs. Assume for simplicity that a constant transport rate equal to unity exists for hauling the good one unit of distance. Thus, the delivered price from a selling site to any buying point is

(2) $$\bar{P} = p + u,$$

where u represents the units of distance to that point from the relevant seller's location. Combining (1) and (2) are solving for q yields

(3) $$q = \left[\frac{v}{b}(a - p - u)\right]^{1/v}.$$

Assume that each of the firms faces production costs consisting of a fixed cost component, F, and a variable cost which involves a constant marginal cost, c:

(4) $$C_i = F_i + c_i Q_i \; i = x, y, z.$$

The x, y, and z subscripts denote the three firms, while Q represents a firm's output. In a spatial world these fixed and marginal cost values need not be identical for survival of geographically separated firms. In fact, they are assumed to differ here in order to explore potential relationships between the three firms' prices. In particular, assume $c = c_x = c_y$, but $c_z > c$. Thus, z is a relatively high-cost producer. The schedules

[2] This functional form has been used extensively in the spatial literature, e.g., Greenhut and Greenhut, Benson (1980, 1984), Benson and Hartigan. Note that v must be greater than -1 in the FOB model which follows because we assume a constant marginal cost, and $v < -1$ implies an upsloping marginal revenue.

$c_i + u$ in figure 1 represent the relative marginal delivered cost relationships envisioned here.

In order to determine the profit-maximizing FOB mill price, the individual demands from equation (3) within each firm's service area must be aggregated:

$$(5)\quad Q_x = \int_0^G \left[\frac{v}{b}(a - p_x - u)\right]^{1/v} du = \frac{b}{v+1}\left[\frac{v}{b}(a - p_x)^{(v+1)/v} - \left(\frac{v}{b}(a - p_x - D)\right)^{(v+1)/v}\right],$$

$$(6)\quad Q_y = \int_0^{D-G} \left[\frac{v}{b}(a - p_y - u)\right]^{1/v} du + \int_0^{D-H} \left[\frac{v}{b}(a - p_y - u)\right]^{1/v} du$$

$$= \frac{b}{v+1}\left[2\left(\frac{v}{b}(a - p_y)\right)^{(v+1)/v} - \left(\frac{v}{b}(a - p_y - D + G)\right)^{(v+1)/v} - \left(\frac{v}{b}(a - p_y - D + H)\right)^{(v+1)/v}\right],$$

$$(7)\quad Q_z = \int_0^H \left[\frac{v}{b}(a - p_z - u)\right]^{1/v} du = \frac{b}{v+1}\left[\left(\frac{v}{b}(a - p_z)\right)^{(v+1)/v} - \left(\frac{v}{b}(a - p_z - H)\right)^{(v+1)/v}\right].$$

The Q_i represent the aggregate demand functions relevant to the FOB pricing firms, while G and H are distances over which X and Z, respectively, sell.

Profit for each firm is

$$(8)\quad \pi_i = (p_i - c_i)\,Q_i - F_i,$$

so profits are maximized when $d\pi_i/dp_i = 0$. Thus, for example, firm X's profit-maximizing decision is represented by

$$(9)\quad \frac{d\pi_x}{dp_x} = \left[\frac{v}{b}(a - p_x)\right]^{(v+1)/v} - \left[\frac{v}{b}(a - p_x - G)\right]^{(v+1)/v} + \frac{v+1}{b}(p_x - c_x)\left[\frac{v}{b}(a - p_x - G)\right)^{1/v}\left(1 + \frac{dG}{dp_x}\right) - \frac{v}{b}(a - p_x)\Big)^{1/v}\Bigg] = 0.$$

The oligopolistic nature of this pricing decision is represented by the boundary conjecture (dG/dp_x). The boundary between two FOB pricing firms' sales areas occurs where delivered prices are equal, so G arises where

$$(10)\quad p_x + G = p_y + (D - G), \text{ or}$$

$$(11)\quad G = \frac{1}{2}(p_y - p_x + D).$$

The boundary conjecture dG/dp_x clearly depends on X's expectations regarding Y's price response because

$$(12)\quad \frac{dG}{dp_x} = \frac{1}{2}\left(\frac{dp_y}{dp_x} - 1\right).$$

The precise value of p_x obtained from equation (9) depends on demand and cost parameters as well as on the size of firm X's sales area (G) and the boundary conjecture. Thus, x's reaction function might be characterized as

$$(13)\quad p_x = p_x\left(a, b, v, c_x, G, \frac{dG}{dp_x}\right).$$

Of course, G, given in equation (11), is a function of p_x and p_y; so, through G, the price set by the firm at X depends on the price set by the firm at Y. Furthermore,

$$(14)\quad H = \frac{1}{2}(p_y - p_z + D),$$

$$(15)\quad p_z = p_z\left(a, b, v, c_z, H, \frac{dH}{dp_z}\right), \text{ and}$$

$$(16)\quad p_y = p_y\left(a, b, v, c_y, G, H, \frac{dG}{dp_y}, \frac{dH}{dp_y}\right).$$

Assumption of specific parameter values and conjectures allows simultaneous solution of equations (11), (13), (14), (15), and (16) for equilibrium prices, such as p_x, p_y, and p_z in figure 1. Thus, the price set by X is, through G, p_y and H, a function of the price set at Z. In

fact, given $v < 0$, (if $v > 0$, price discrimination rather than FOB pricing is likely, as explained below) comparative statics analysis implies that

$$\frac{dp_x}{dp_z} > 0. \tag{17}$$

The actual comparative statics analysis of the integration process implied by this model is not presented here because the results are intuitively obvious (Benson 1980). If firm Z lowers price for some reason, H would expand ($D - H$ would shrink) prompting firm Y to lower price; G in turn would shrink ($D - G$ would expand), and firm X would lower its price. The price set by X is impacted by cost and demand conditions which Z faces (and vice versa). By the definition of geographic market integration used here, X, Y, and Z are all in the same market because each firm's price depends on the prices set by the other two.

However, this integration likely represents a dynamic process if spatial oligopolistic competition underlies the price formation process. Initial price reactions and their feedbacks can lead to additional price changes as the market adjusts toward a new equilibrium for comparative statics analysis. Reaction functions such as equations (13), (15), and (16) imply a sequence of reactions and re-reactions. The full price adjustments can take time. In addition, as already noted, the fully adjusted equilibrium prices need not be equal or differ exactly by transport costs (recall the discussion of fig. 1). Indeed, given $c_z > c_x$, $p_z > p_x$, but $p_x + u_{xz} > p_z$ (u_{xz} represents the distance from X to Z). Prices may be highly interdependent in a spatial setting without net price uniformity (price less transportation costs) rising. Arbitrage only guarantees that prices at different spatial buying sites will not differ by more than the transport cost of shipping the product from one site to another. It does not imply that prices net of transfer costs will be the same; indeed, they can differ for many reasons in a spatially interdependent market.

The magnitude of price responses need not be identical. Consider firm Y's response to firm X's original price change. Firm Y may wish to regain its lost geographic market share by exactly matching X's price change, but such a response will also generate a price reaction by Z (as well as further price changes by X). If Y does not fully match X's price change, then Y serves as a buffer between X and Z. The larger the number of intermediate selling sites between two specific sellers, the weaker the price linkage. Mulligan and Fik (1988, 1989) demonstrate mathematically that a distance-decay effect occurs in spatial competition models. More distantly located competitors are linked indirectly and, *ceteris paribus*, the price response will be weaker.

Spatial Price Discrimination

The value of the parameter v in the demand function [equation (3)] is one important determinant of whether or not firms in the market can practice price discrimination. A spatial firm which faces no direct competition for customers at a particular buying point will set a profit-maximizing price at that point unless prevented from doing so (e.g., by consumer arbitrage or by legal/institutional constraints). For instance, firm X will set price for a customer located at X by equating marginal revenue and marginal cost:

$$\bar{P}_x (1 - (1/e)) = c_x, \tag{18}$$

where e is the own-price elasticity of demand. From equation (1), $d\bar{P}/dq = -bq^{v-1}$ and $bq^v = v\,(a - \bar{P})$, so

$$e = \bar{P}/(v(a - \bar{P})). \tag{19}$$

Substituting (19) into (18) provides

$$\bar{P}_x (1 + v) - va = c_x. \tag{20}$$

For consumers located at some distance from X, transport costs are netted from marginal revenue or added to marginal cost

$$\bar{P}_{xd} (1 + v) - va = c_x + u, \tag{21}$$

where $\bar{P}_{xd}$ represents delivered price from x to any point in the market. Solving equation (21) for $\bar{P}_{xd}$ yields firm X's discriminatory delivered price schedule.

$$\bar{P}_{xd} = (1/(1 + v))\,(va + c_x) + (1/(1 + v))u. \tag{22}$$

The first term on the right-hand side of equation (22) is the price at point X [see equation (20)], while the slope of the delivered price schedule as u increases is $(1/(1 + v))$. The slope of an FOB schedule is unity because the transport rate is assumed equal to one. Therefore, a delivered price schedule with a slope of less than one implies freight absorption and discrimination in favor of distant buyers (or against near buyers). A slope greater than one, implies phantom freight and discrimination in favor of near buyers (against

distant buyers). Thus, $v > 0$ means that freight absorption is profitable, while $v < 0$ implies that it is not.

Profitable consumer resale or arbitrage is not possible when freight is absorbed. However, arbitrage should prevent phantom freight and discrimination in favor of near buyers (see Benson 1984 for more detail). Thus, $v < 0$ implies that the best spatial firms can likely do is set FOB prices. As a consequence, the theoretical analysis of price discrimination was developed assuming $v > 0$ and FOB pricing assuming $v < 0$. Of course, FOB pricing may also arise when price discrimination is prevented even though $v > 0$ (e.g., legal sanctions may prevent spatial price discrimination, or consumers may pay the transport cost themselves by traveling to pick up the product).

Similar schedules to equation (22) can be derived for Y and Z. Assuming the same parameters, discriminatory schedules would produce higher price intercepts and flatter schedules than the FOB schedules depicted in figure 1. Consumers would buy from the firm offering the lowest delivered price, so market boundaries occur where delivered price schedules are equal.

Because prices are set independently at each buyer site, interdependence only applies where delivered prices are equal. In the example developed here, this condition occurs at only one point between X and Y and between Y and Z. Spatial price discrimination is not restricted to monopoly, and spatial competitors can discriminate in order to invade rival's markets, producing considerable market overlap (Greenhut and Greenhut). Thus, discrimination may break the linkage that implies extensive market integration, as under FOB pricing. A complete breakdown in market integration requires constant marginal costs.

When marginal costs are upsloping, the spatial price discriminator does not equate marginal cost to the net marginal revenue on sales at each buyer location. Instead, the relevant marginal cost is that which applies to the last unit of total sales over the firm's entire marketing area (Greenhut, Norman and Hung, pp. 180–96). Spatial markets consisting of price discriminatory oligopolists are interdependent because price changes in one firm affect its market fringe, moving neighboring firms down along their original marginal cost schedules. Thus, other firms lower profit-maximizing discriminatory prices to all buyer locations, firms consider rival responses to potential price adjustments, and lagged price adjustments and feedbacks characterize the adjustment to an equilibrium. Thus, market integration implications similar to those discussed above under oligopolistically competitive FOB pricing can arise under oligopolistically competitive spatial price discrimination, given nonconstant marginal costs.[3]

Basing-Point Pricing

Basing-point pricing systems generally result from an organized oligopoly arrangement, either price leadership or collusion (Greenhut, Scherer). Under this system the mill or base price is set at a particular production site (sites under a multiple base-point system) or basing point, and the delivered price to any buyer location is the base price plus transportation costs.

In figure 2, site A is the basing point. The price at A (p_A) is set, perhaps jointly by several spatially dispersed firms or perhaps by the basing point firm (or firms) acting as a price leader. Firms located at other sites (for example, B and C) adopt the delivered price schedule from A ($p_A + tu$) for all sales. Thus, prices net of transport costs are equal. Sales to the left of B and C's locations require freight absorption by the firms at those locations, while sales to the right involve "phantom freight" because they would normally charge a price below P_B and compete for market area such as in figure 1. If the price at A were to change for some reason, all other prices would change by the same amount. Furthermore, collusion or price leadership implies virtually instantaneous price adjustments with no feedbacks.

Clearly, prices are interdependent as the intuitive definition of market integration suggests. Moreover, any arbitrarily chosen regional boundaries established over this market (e.g., at political boundaries) would result in interregional trade because the prices charged by all firms are exactly the same at all locations. Consumers do not differentiate among sellers by location. Thus, the firm at A probably sells through the AC space and firms at B and C may sell all the way back to A if freight absorption is not too great. Under an effective single basing-point system, prices will differ exactly by transportation costs.

[3] The constant marginal cost assumption also influences comparative statics under FOB pricing, given $v > 0$ (thus assuming some legal or institutional constraint prevents price discrimination). If $v > 0$ and marginal costs are constant, a seller may raise price as its market shrinks (Benson 1980, Benson and Hartigan, Capozza and Van Order); so equation (17) need not hold. However, an upsloping marginal cost will reestablish (17) even when $v > 0$.

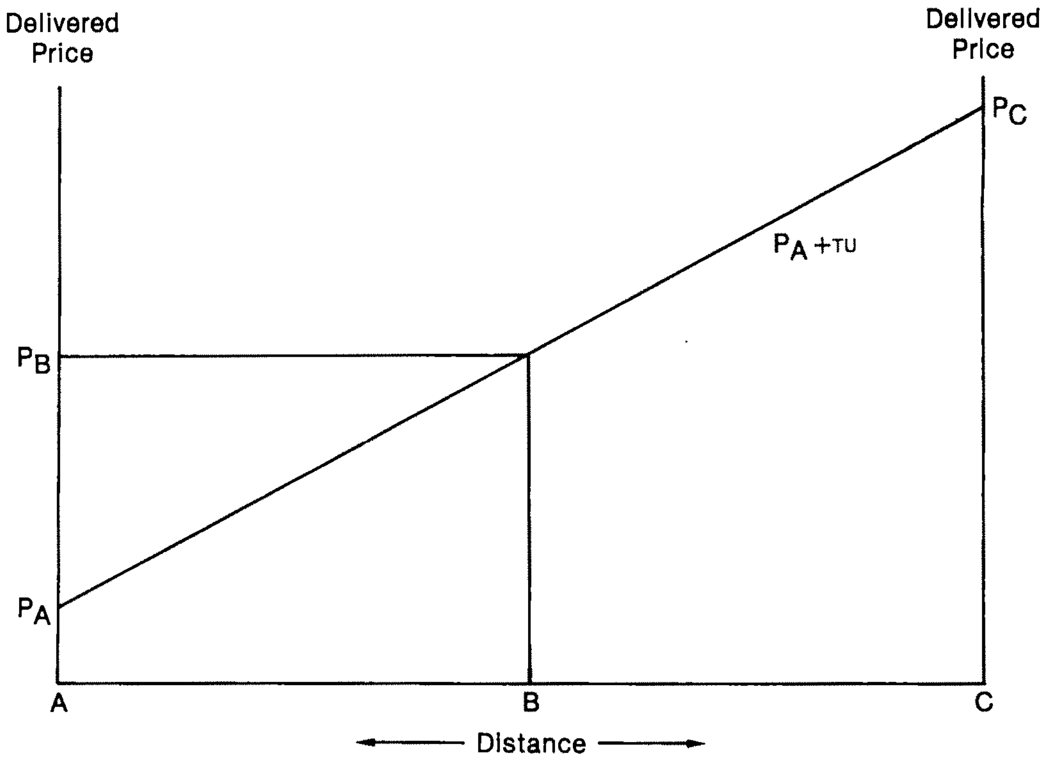

Figure 2. Basing-point pricing

Implications for Empirical Tests

Market integration studies have emphasized applications to food staples in developing countries, most notably Nigeria and India (see Harriss for a review of these studies). Different, but related, empirical techniques have been used to test spatial market integration. High price correlations are often taken to infer integration (e.g., Jones, Harriss, Uri and Rifkin, Blyn). In addition, price differences between markets, relative to transfer costs (Stout and Feltner, Hays and McCoy) or normal seasonal fluctuations (Delgado), provide other approaches to determining integration. However, these empirical tests of market integration are essentially tests to see which spatial pricing system underlies the price formation process.

The usual definition in the literature is that integrated markets are those where prices are determined interdependently. This has generally been assumed to mean that price changes in one market will be fully passed on to other markets (or the result has been derived from a Takayama-Judge model). In this context, Ravallion (p. 105) discusses both short- and long-run market integration. With short-run integration, price changes are fully and immediately passed on to other markets with no lagged effects. Long-run integration requires that a unit price change is fully passed on over time, but with the potential for lagged effects. In principle, however, the Ravallion approach is consistent in its general expectations with the price correlation and net spatial price difference approaches described earlier, which rely on all activity within a region taking place at a point.

Ravallion developed his market integration tests for a central urban market with interlinked local (rural) markets where trade with the central market was the dominant feature of the price formation process.[4] This implies that the rural

[4] Systems like this have been characterized as "competitive" basing point systems (e.g., Haddock). In fact, base point pricing can conceivably arise without collusion or price leadership, but the necessary conditions are very limiting (Benson, Greenhut, and Norman). Thus, a more accurate characterization of such a system is that competitive FOB pricing exists between various central marketing points, and the rural markets are simply transshipment terminals. Alternatively, they may actually involve a price leadership basing point arrangement with the central market firms as the dominant firm price leaders and the smaller rural firms as price takers. The following presentation suggests a statistical procedure for determining whether such a system is competitively or cooperatively produced.

markets are relatively minor. However, extension to a linked framework, as developed above, is straightforward by evaluating all bivariate price relationships in the spatial area under consideration. Consider the model

$$(23)\quad X_t = \sum_{j=1}^{n} a_j X_{t-j} + \sum_{k=0}^{m} b_k Z_{t-k} + E_t,$$

where X_t and Z_t are the prices in location X and Z at time t, E_t is the error process, and the fixed parameters are a_j and b_k. In this simplified version of the Ravallion model the market integration tests remain as

(*a*) independence:

$$b_k = 0\ (k = 0, 1, \ldots, m),$$

(*b*) short-run integration (strong form):

$$b_0 = 1;\ a_j = b_k = 0 \quad (j = 1, 2, \ldots, n;\ k = 1, 2, \ldots, m),$$

(*c*) short-run integration (weak form):

$$b_0 = 1;\ \sum_{j=1}^{n} a_j + \sum_{k=1}^{m} b_k = 0,$$

(*d*) long-run integration:

$$\sum_{j=1}^{n} a_j + \sum_{k=0}^{m} b_k = 1.$$

Price interrelationships in the system can be evaluated by considering all market pair combinations.

The test of independence requires that the contemporaneous and lagged price effects at one location are independent of prices at another location ($b_k = 0$, all k). If consumers and producers are spatially distributed, this possibility is predicted by spatial price discrimination with constant marginal costs. Under the other spatial pricing systems described above, $b_k \neq 0$ is expected to hold.

The strong form of short-run integration requires basing-point pricing if consumers and producers are not concentrated at single points and prices differ by transportation costs. In this case price adjustments are fully reflected in the same time period ($b_0 = 1$) with no lagged effects ($a_j = b_k = 0$; j, $k \neq 0$). An effective basing-point system is the only theoretical spatial model which produces this expectation, given spatially distributed buyers and sellers, and significant intraregional transport costs.

The other widely used spatial models (competitive FOB oligopoly and spatial price discrimination) do not produce these same expectations. Basing-point systems generally arise out of a noncompetitive institutional structure and are not usually considered desirable.[5] (They are frequently attacked under the antitrust laws.) This suggests that concerns about the lack of market integration in some empirical studies should be discounted; their expectations are not based on a model which is expected to generate desirable results if buyers and sellers are spatially dispersed in the market being examined. Under such circumstances, the evidence (previously interpreted as a lack of market integration) suggests that cartelization, in the form of a perfect basing-point pricing system, is not generally observed. Strikingly, the typical conclusion that highly integrated markets (that is, markets in which price movements are highly correlated and prices differ exactly by transport costs) are caused by competition and imply an efficient market is reversed: such markets are caused by collusive basing-point pricing and tend to be relatively inefficient.

The weak version of the short-run integration test requires that the lagged effects vanish on average ($\Sigma_{j=1}^{n} a_j + \Sigma_{k=1}^{m} b_k = 0$); this result is consistent with a less than perfect basing-point system. For instance, if this test applies for all the relevant marketing points, then a tacitly collusive arrangement may exist and time is required to search for the new equilibrium price. If, on the other hand, the result applies for a subset of the interdependent marketing points, then an incomplete cartel may be in operation. Price adjustments set in motion within the base point system cause competitive reactions by firms outside the basing-point arrangement which feed back into the base point price determination process, and vice versa. Thus, lags and feedbacks are evident between firms in the basing-point arrangement and those outside it.

The two short-run integration tests constitute tests of an underlying basing-point system. Along with the Takayama and Judge criterion of equal spatial prices (net of transfer costs) over time, these tests allow examination of the underlying market behavior in spatial price generation.

In the long-run integration test, all contemporaneous and lagged effects sum to one. In effect, price changes in one region net out, in a dynamic fashion, to exactly equal price changes in the other. Because each short-run test implies

[5] Such a system might be competitively produced, but the necessary conditions are quite limiting. See footnote 4 for related discussion.

long-run integration (Ravallion), this test is a feature of a basing-point system. However, the short-run tests may be rejected and the long-run test accepted. This would be consistent with price reactions equal to one for the competitive FOB oligopoly and perhaps for increasing marginal cost price discriminatory models. However, exact price matching over the longer term is not a requirement of these models, only an empirical possibility.

An Empirical Example: Hog Prices in Canada

Weekly hog prices for five Canadian cities (Edmonton, Calgary, Saskatoon, Winnipeg, and Toronto) were taken from the Livestock and Meat Trade Report for the period 9 January 1965 to 20 December 1975. Data for Montreal, the other major hog market in Canada, were not published subsequent to July 1970, so this city is excluded from the analysis. In total, 572 weekly observations of average prices were available. From 9 January 1965 to 28 December 1968, Grade A dressed hog prices were used, and for the remaining time Dressed Index 100 hog prices were analyzed. This eleven-year period includes the time period when electronic exchanges were introduced for marketing hogs; thus, it represents a potential readjustment in the price formulation process in Canada. Therefore, the ability of the empirical tests to detect changes in pricing systems could be evaluated. In addition, this general time period has had considerable scrutiny. Concerns about market pricing efficiency resulted in a major price study (Canadian Pork Council) and in a major anticombines case.[6]

Both buyers and sellers are spatially dispersed, and transportation costs are significant; so these data are particularly well suited for evaluation of spatial prices and the form of the pricing system which is implicit in the market integration tests. Generally, hog production is dispersed across Canada, although not always evenly, and slaughtering occurs at the major cities included in the analysis. Hog production in each province was relatively constant during the 1965–69 time period. However, during the 1970–75 period, production trended slightly upward in Saskatchewan and Manitoba, decreased somewhat in Ontario, and fluctuated around the historical average in Alberta (Canada Pork Council). A substantial exported surplus developed in Saskatchewan and Manitoba, and the price differential in these provinces fell relative to U.S. prices. In addition, during this time Ontario moved from a position of self-sufficiency to a pork deficit.

Other institutional changes were occurring during the early 1970s. In Alberta (1969), Saskatchewan (1973) and Manitoba (1971) marketing boards for hogs were formed, and the pricing system changed. Electronic exchanges for selling hogs were instituted in Alberta and Manitoba, while Saskatchewan developed a formula pricing system for sales from the marketing board to packers. Finally, substantial rationalization of the packing industry occurred. In response to low levels of capacity utilization (estimated at about 30% by Canada West Foundation) a large number of plants either closed or ceased to slaughter hogs.

The price data were first differenced in order to represent price changes from period to period. This allowed the data analysis in a manner consistent with the theoretical models. Price levels were highly volatile during the latter half of the data set, and the transformation to price differences allows the empirical evaluation to focus on the interdependence of price changes rather than price levels. This is consistent with the theoretical model development, and interactions of price changes between different locations should not be seriously affected by volatile overall price levels. Additionally, based upon inspection of the estimated autocorrelation functions, differencing transformed the data into stationary series.

The empirical tests are based on estimated OLS versions of equation (23) for all combinations of market pairs for the five cities (20 regressions per time period). This exhaustive evaluation of price response equations allows the evaluation of the form (or forms) of spatial pricing for hogs. A simultaneous approach would evaluate the generalized version of equation (23) using vector autoregression. However, beyond the well-known tendency of severe multicollinearity using this approach, there is an additional cost. Weaker price responses, caused by the linked interdependence of spatial oligopoly pricing systems, should be observed in the $\bar{R}^2$s resulting from the OLS estimates of equation (23) for each market pair. With more intermediary markets the price response is less direct. This information would be lost by using vector autoregression.

The data were divided into two time periods for analysis. The first coincides with the period

[6] *Reason for Judgment in Her Majesty the Queen* v. *Canada Packers Inc. and Intercontinental Packers Ltd.*

of relative stability in the market (9 Jan. 1965 to 25 July 1970), while the second represents a period with considerable institutional change (1 Aug. 1970 to 20 Dec. 1975). The criterion for determining the break point is arbitrary. However, it coincides with the date after which prices for Montreal ceased to be publicly reported by Agriculture Canada, and it allows evaluation of any differences in pricing systems during the two periods. Therefore, the sensitivity of the empirical procedure to structural and institutional factors can be evaluated.

The correct dynamic process given in equation (23) cannot be determined theoretically. Mechanical procedures can be applied (Bessler and Brandt) when a priori information is not available. In all cases, the Ljung-Box Q-statistic of the unrestricted regressions implied that autocorrelation was not a problem when eight lags were specified.[7] Therefore, the empirical tests are all conducted with eight lags (n, m = 8).

Evaluation of the market integration or spatial pricing tests involved F-tests of the regressions implied by equation (23) with the tests imposed as constraints, combined with analysis of spatial price differences. Tables 1 and 2 show the F-statistics for the two time periods and table 3 reports means and standard deviations of price differences between Toronto and the other markets.

Price differences. Price differences between Toronto and the other markets display different results for the two time periods. In period 1, price differences generally correspond to differences in transfer costs. For example, the average Toronto-Calgary difference is \$3.52, while the Toronto–Saskatoon difference is \$2.74. The Toronto–Edmonton price difference is roughly equivalent to transfer costs reported by the Canadian Pork Council. During the second period, the relationship between Toronto prices and the other markets changes considerably. Not only are price differences greater in all cases (probably reflective of general price inflation during the period), but they tend towards equality. Thus,

[7] Initial testing with four lags resulted in rejection of the null hypothesis of no autocorrelation. In addition, although choice of lag is by nature a difficult issue, eight weeks was a sufficient number to allow for interactive pricing between competing regions to run its course. "Hannan's Criterion" (Hannan) was suggested by a reviewer as an alternative ad hoc procedure. "Long-run" in these types of tests should be interpreted with caution because long-run in the normal economics sense is not being tested.

Table 1. F-Statistics for Pricing Behavior Tests—Jan. 65–July 70

Dependent Variable[a]	Independent Variable[a]	Independence[b] $b_k = 0$	Perfect Basing-Point Pricing[c] $b_0 = 1$; $a_j = b_k = 0$	Incomplete Basing-Point Pricing[d] $b_0 = 1; \Sigma_{j=1}^{n} a_j + \Sigma_{k=1}^{m} b_k = 0$	Long-Run Price Matching[e] $\Sigma_{j=1}^{n} a_j + \Sigma_{k=0}^{m} b_k = 1$
CAL	EDM	393.23*[f]	11.91*	7.58*	1.93
CAL	SAS	57.47*	17.95*	94.00*	13.04*
CAL	WIN	51.88*	18.28*	100.13*	12.20*
CAL	TOR	27.80*	8.56*	34.19*	4.72*
EDM	CAL	347.07*	10.46*	0.23	0.02
EDM	SAS	58.97*	15.72*	82.17*	12.64*
EDM	WIN	46.61*	16.52*	87.44*	12.26*
EDM	TOR	26.31*	8.37*	41.93*	5.03*
SAS	CAL	51.20*	4.04*	0.20	0.00
SAS	EDM	56.38*	3.74*	0.09	0.00
SAS	WIN	518.17*	17.11*	14.62*	0.10
SAS	TOR	31.22*	3.39*	8.72*	0.73
WIN	CAL	43.83*	3.71*	0.14	0.11
WIN	EDM	45.28*	3.75*	0.06	0.11
WIN	SAS	468.87*	14.24*	1.75	1.37
WIN	TOR	32.43*	2.86*	5.05*	0.60
TOR	CAL	19.36*	5.37*	20.96*	9.48*
TOR	EDM	19.32*	5.90*	23.97*	9.89*
TOR	SAS	23.17*	10.96*	64.95*	17.87*
TOR	WIN	27.11*	11.55*	69.74*	16.97*

[a] *CAL*, Calgary; *EDM*, Edmonton; *SAS*, Saskatoon; *WIN*, Winnipeg; *TOR*, Toronto.
[b] $F(9, 263)$.
[c] $F(17, 263)$.
[d] $F(2, 263)$.
[e] $F(1, 263)$.
[f] Single asterisk indicates rejected at 95% level of confidence.

Table 2. *F*-Statistics for Pricing Behavior Tests—Aug./70–Dec./75

Dependent Variable[a]	Independent Variable[a]	Independence[b] $b_k = 0$	Perfect Basing-Point Pricing[c] $b_0 = 1$; $a_j = b_k = 0$	Incomplete Basing-Point Pricing[d] $b_0 = 1$; $\Sigma_{j=1}^{n} a_j + \Sigma_{k=1}^{m} b_k = 0$	Long-Run Price Matching[e] $\Sigma_{j=1}^{n} a_j + \Sigma_{k=0}^{m} b_k = 1$
CAL	EDM	198.92*[f]	16.62*	10.73*	1.88
CAL	SAS	35.50*	5.71*	5.30*	2.80
CAL	WIN	46.06*	8.17*	16.71*	0.02
CAL	TOR	37.33*	8.18*	27.02*	0.06
EDM	CAL	223.12*	14.35*	0.84	0.17
EDM	SAS	26.94*	7.09*	5.04*	3.29
EDM	WIN	43.64*	6.42*	7.73*	0.01
EDM	TOR	33.65*	7.95*	19.78*	0.03
SAS	CAL	43.40*	12.90*	51.41*	3.93*
SAS	EDM	31.96*	19.43*	79.03*	5.65*
SAS	WIN	220.10*	39.30*	106.03*	5.71*
SAS	TOR	42.75*	15.58*	77.16*	0.08
WIN	CAL	40.59*	9.38*	24.21*	11.01*
WIN	EDM	37.98*	11.71*	41.10*	12.22*
WIN	SAS	141.15*	20.09*	23.41*	19.15*
WIN	TOR	48.82*	8.95*	27.30*	0.60
TOR	CAL	30.59*	7.80*	24.47*	15.88*
TOR	EDM	25.16*	10.88*	38.54*	16.94*
TOR	SAS	24.33*	5.71*	11.15*	16.01*
TOR	WIN	43.34*	6.47*	11.30*	6.63*

[a] *CAL*, Calgary; *EDM*, Edmonton; *SAS*, Saskatoon; *WIN*, Winnipeg; *TOR*, Toronto.
[b] $F(9, 255)$.
[c] $F(17, 255)$.
[d] $F((2, 255)$.
[e] $F(1, 255)$.
[f] Single asterisk indicates rejected at 95% level of confidence.

in period 2 relative prices across markets no longer reflect differences in transfer costs to other markets.

Independence. In all cases the null hypothesis of independence is rejected. Thus, no evidence of price discrimination is found under conditions of constant marginal costs in either period.

Perfect basing-point pricing. The strong version of short-run integration is rejected in all cases. Thus, there is no evidence of a perfectly functioning basing-point pricing system during either period. In several cases inspection of the individual regression coefficients indicated that $b_0 = 1$, but lagged effects were significant.

Table 3. Means and Standard Deviations for Price Differences

	TOR–CAL	*TOR–EDM*	*TOR–SAS*	*TOR–WIN*
Period 1				
Mean	3.52	3.60	2.74	1.71
S.D.	1.06	1.05	1.08	1.11
Period 2				
Mean	4.42	4.20	4.40	3.51
S.D.	1.53	1.59	1.43	1.31

Incomplete basing-point pricing. In period 1, the weak form of the short-run integration test is not rejected in six cases. Prices in the three western markets appear to be interrelated by a loose form of basing-point pricing where Calgary is the basing point. The evidence suggests an unidirectional system where (*a*) Edmonton bases on Calgary; (*b*) Saskatoon bases on Edmonton and Calgary; (*c*) Winnipeg bases on Saskatoon, Edmonton, and Calgary. This western basing-point system is apparently competitively linked with Toronto, however, and this may explain the observed lags and feedbacks.

In period 2 the results are considerably different; in only one case do we fail to reject the weak-form constraint. In the second period, prices in Edmonton continue to be based on Calgary prices.

The evidence from this test is striking. The data indicate that the more widespread basing-

point system evident in period 1 broke down. This result contrasts with the anticombines case, cited earlier, which alleged price fixing by the Alberta-based packers throughout the entire eleven-year period.

Long-run price matching. In period 1, the restriction of exact, but lagged, price matching is rejected in ten cases. In Calgary and Edmonton, price changes in one market are fully reflected in the other, but neither fully reflects changes in the other three markets. The intermediate cities, Saskatoon and Winnipeg, fully reflect other markets, while this test is always rejected for Toronto.

The results are considerably different for period 2. In all cases this restriction is not rejected for Calgary and Edmonton, while it is only accepted for Saskatoon and Winnipeg when Toronto prices are used as independent variables. Once the basing-point pricing system broke down, the magnitude of price interactions and responses between markets changed substantially. In particular, lagged responses became more important for the two Alberta markets.

Distance decay effects. The unrestricted $\bar{R}^2$s for the two periods are given in tables 4 and 5. The distance-decay feature of spatial competition is evident in both periods. The $\bar{R}^2$-values decline with distance and/or the number of intermediate points, reflecting the linked nature of the price reaction functions given above. However, differences between the two time periods are evident. In particular, the increased pricing interdependence associated with the disappearance of the basing-point system is evident in the $\bar{R}^2$-values. The relative importance of Saskatoon and Winnipeg price changes as predictors of Calgary and Edmonton price changes is diminished. In general, $\bar{R}^2$-values are lower for all markets in period 2. Because of the increased competition associated with the breaking down of the basing-point system, the $\bar{R}^2$s of the paired market price responses are reduced. This is caused by a more rivalrous price determination process where price changes in additional markets must be considered. Thus, a lower level of correlation between any pair of price series should be expected.

Market efficiency. The marketing boards established in Alberta, Saskatchewan, and Manitoba were initially proposed to create more equitable and efficient markets for slaughter hogs. The electronic marketing systems implemented in Alberta and Manitoba were designed to create more competitive bidding by packers. In Saskatchewan, a formula pricing arrangement was developed to link provincial prices more closely to other markets. In all three cases, the primary emphasis was on designing pricing systems that facilitated exchange and reflected underlying

Table 4. Adjusted *R*-Squares—Jan./65–July/70

	Independent Variables				
Dependent Variables	*CAL*	*EDM*	*SAS*	*WIN*	*TOR*
CAL		0.93	0.69	0.67	0.53
EDM	0.93		0.70	0.67	0.53
SAS	0.64	0.66		0.94	0.52
WIN	0.60	0.61	0.94		0.53
TOR	0.45	0.45	0.49	0.53	

Table 5. Adjusted *R*-Squares—Aug./70–Dec./75

	Independent Variables				
Dependent Variables	*CAL*	*EDM*	*SAS*	*WIN*	*TOR*
CAL		0.87	0.56	0.62	0.60
EDM	0.88		0.47	0.59	0.53
SAS	0.62	0.55		0.89	0.61
WIN	0.59	0.57	0.83		0.63
TOR	0.57	0.52	0.52	0.64	

supply and demand conditions. None of the marketing boards was given authority to manipulate prices through supply management.

The disintegration of the basing-point system and movement to a more competitive FOB system roughly coincided with the introduction of these marketing innovations. However, other institutional changes (interregional supply/demand balances and rationalization of the packing industry in western Canada) were also occurring, so it is difficult to clearly establish a direct causal link. Adomowicz, Baah, and Hawkins suggest that shifts in market interdependency between Alberta and other major markets may have been caused by institutional changes instituted by the marketing board in Alberta. However, given the theoretical arguments presented above, the implications for market efficiency would be interpreted somewhat differently. High levels of price interdependence, in conjunction with price differences between hog buying locations that reflect transportation costs, is symptomatic of a collusive (overt or tacit) pricing system.

Conclusions

Studies of integration for spatial markets have explicitly or implicitly drawn their implications from a theory of market price formation which assumes no intraregional transport costs. Such studies have primarily relied upon price correlations and regressions that analyze the dynamic price adjustment patterns. Rarely, if ever, have prices been found to be highly correlated and differ between two points by transportation costs, thus indicating that the markets under study are not highly integrated and perhaps that they are not very efficient. An alternative theoretical interpretation for such results is suggested here, based on the assumptions that both buyers and sellers are spatially dispersed and intraregional transport costs are significant. These assumptions imply that the market is a linked oligopoly (or oligopsony). The implications of this alternative theory are illustrated by focusing on market integration tests proposed by Ravallion which allow certain predictions of various spatial pricing systems that may underly oligopoly (oligopsony) market price formation to be examined. For example, when combined with the criterion that prices between two points should differ by transportation costs, short-run integration standards are effectively tests of basing-point pricing.

To illustrate the implications of the theoretical analysis, the Ravallion methodology was applied to hog prices in Canada. Noncompetitive pricing, in the form of a basing-point pricing system for hogs, was detected for a subgroup of Canadian hog markets between 1965 and 1970. The tests were sensitive to institutional characteristics of the market. The results suggest that this pricing system disintegrated during the 1970–75 period, a time when substantial changes in the Canadian hog market occurred, and was replaced by a more competitive FOB pricing system.

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The Value of Weather Information in Market Equilibrium

Bruce A. Babcock

Increased accuracy of weather forecasts does not necessarily increase commodity supply or farmer welfare. This study presents a stylized model of competitive production with rational expectations and demonstrates that improved weather information harms farmers facing an inelastic demand. Contrary to the conclusions of previous studies, the decline in farmer welfare does not require an expansion in expected supply. Better weather information may signal farmers to produce less on average under an inelastic demand. A supply decrease occurs when increases in the physical productivity of applied inputs are dominated by adverse price consequences.

Key words: market equilibrium, rational expectations, value of information, weather forecasts.

Widespread drought reinforces the notion that random weather processes can have both micro and macro effects on farmers. The productivity of farm inputs is affected as are output and input prices. Forecasts about weather, therefore, can affect the decisions of farmers in two ways: first, from the direct impact on physical productivity, and, second, through the profitability effects of expected price changes.

The impacts of weather forecasts on the physical productivity of input decisions are well studied (e.g., Byerlee and Anderson; Tice and Clouser; Rosegrant and Roumasset; Hashemi and Decker; Baquet, Halter, and Conklin; Stewart, Katz, and Murphy). However, the impacts of weather information on market prices have received little attention. One exception is Lave's analysis of the California raisin industry. He concludes that even a modest increase in supply from rainfall protection would lower total industry profits because of the inelastic demand for raisins. Thus, the raisin industry as a whole would be better off with less than perfect weather forecasts. However, Lave stopped short of examining how raisin producers would react to the knowledge that better weather forecasts lead to lower average prices. Presumably, the supply of raisins would decrease, thereby ameliorating some of the adverse price effects.

Typically, the value of information to an individual producer is calculated as the difference between expected returns (or utility) using the information and expected returns without the information, with both expectations taken with respect to the more informed distribution. The aggregate value of information is the sum of the individuals' values. Both the individual and the aggregate value of information are nonnegative using this approach. Lave's analysis reveals the problem with calculating the value of information when the use of the information can lead to price effects. Such market effects cannot be captured by the usual method of calculating the value of information.

Farmers' reactions to the knowledge that the use of information will change output price depend on whether they act cooperatively or noncooperatively. Monopoly models can be used to examine how farmers will use information if they cooperate in setting output levels. Such collusive behavior may characterize decisions by farmers who grow crops covered by marketing orders that effectively control quantities, and hence, prices. However, most crops are not covered by marketing boards, and individual producers generally make their own supply decisions. Widely available information that is used by many producers can create a price externality (external to the control of individual producers). Models of noncooperative behavior must be used to capture these effects.

The purpose of this paper is to examine how

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the value of weather information is changed with improvements in the accuracy of forecasts when farmers act noncooperatively. Farmers are assumed risk-neutral, rational, and competitive. Further, each farmer is assumed to contribute a sufficiently small fraction of total output, so any individual's supply decision does not affect output price. Under these conditions better weather information could lead to a lower aggregate value of information. It is also shown, in contrast to Lave, that this result does not require an expansion in average supply.

The Model

Consider a competitive farmer with a crop yield which depends on the level of a controllable input, x, and an uncontrollable weather input, w, the level of which is known after x is applied. For simplicity, assume that w can only take on two values, w_g and w_b, and that the historical probability that w_g occurs is q. Denote the production function facing the farmer as

$$y = f(x, w),\ w = w_g \text{ or } w_b, \tag{1}$$

where y represents yield per acre. It is assumed that $f(x, w_g) > f(x, w_b)$ for all x.

To highlight the relationship between one region's weather forecast and output price, total supply is assumed to come from a single representative farmer. This farmer operates with the production function given by (1). In addition, this farmer is a risk-neutral price taker with rational expectations concerning output price. Although the demand function is nonstochastic, the price that the farmer will receive is stochastic before the weather variable is observed because of uncertain output. This formulation allows joint consideration of production and price uncertainty (Newbery and Stiglitz).

The assumption that the industry consists of one competitive producer with rational expectations is equivalent to assuming a large number of identical producers, none of which is large enough to affect output and each of which has rational expectations. The assumption of rational expectations means that each producer knows how the rest of the producers in the market will respond to changes in information, so the resulting distribution of output price is implied by the aggregate actions of all producers. No individual producer will find it profitable to diverge from what is optimal for all other producers because the action of any single producer does not affect output price.

Suppose that the farmer receives a probability forecast about the future level of w when x is applied. Let ρ represent the forecasted probability that future weather will be w_g. Assume that the forecaster is "correct" in that w_g occurs 60% of the time when the forecaster says that the probability of receiving w_g is 60%. Assume that farmers adopt the forecasted probability as their own posterior probability.[1] Let $g(\rho)$ denote the probability distribution function of ρ. The probability forecast ρ can take on any value between 0 and unity depending on observable weather conditions before the forecast is made and on the skill of the forecaster.

The farmer chooses the level of a variable input to apply after receiving a given forecast of future weather. The objective function and first-order condition for a specific value of ρ (e.g., $\rho = \rho_0$) are

$$\max_x E(\pi|\rho = \rho_0) = \rho_0 P[f(x, w_g)]f(x, w_g) + (1 - \rho_0)P[f(x, w_b)]f(x, w_b) - P_x x,$$

$$\rho_0 P[f(x, w_g)]f_x(x, w_g) + (1 - \rho_0)P[f(x, w_b)]f_x(x, w_b) - P_x = 0, \tag{2}$$

where $P(\cdot)$ is the demand function. Denote the solution to (2) as $x(\rho_0)$.

When choosing the level of x to apply, the farmer does not consider the change in output price implied by the level chosen because any single farmer faces a perfectly elastic demand curve. However, because the farmer uses all available information, the price distribution used to choose x in (2) is consistent with the choice of x. If this were not true, the farmer's choice would be suboptimal. Therefore, the derivative of output price with respect to input use does not appear in (2).

This concept of equilibrium naturally follows from the assumptions that no farmer is large enough to affect price and that farmers act noncooperatively. Relaxing either of these assumptions would yield another type of equilibrium (Cornes and Sandler).

[1] This paper does not focus on how farmers process information; rather, it focuses on the effects of more reliable forecasts on the value of information. The translation of objective probabilities (data) into posterior probabilities with Bayes' rule would needlessly complicate the analysis. To give the analysis a more Bayesian interpretation, ρ can be considered a posterior probability formed by processing a signal from the weather forecaster, rather than a forecast itself. The results developed in the paper are applicable to either interpretation.

The value of weather information is given by

$$(3)\quad VI = \sum_{\rho} \{\rho\pi[x(\rho), w_g] + (1-\rho)\pi[x(\rho), w_b] - \rho\pi(x_h, w_g) - (1-\rho)\pi(x_h, w_b)\}g(\rho),$$

where $\pi(\cdot)$ is the profit function for different forecasts, and x_h is the optimal amount of x employed using historical weather probabilities. Because x_h is not a function of ρ, the last two terms in (3) can be written

$$-\pi(x_h, w_g)\bar{\rho} - \pi(x_h, w_b)(1-\bar{\rho}),$$

where $\bar{\rho} = \Sigma\rho g(\rho)$ measures the weighted sum of conditional probabilities that good weather will occur. Given the assumption of correct forecasts, $\bar{\rho} = q$.

Increases in forecast accuracy come about with fewer forecasts of ρ in the vicinity of q, and more around zero and one. Perfect forecasts are given by forecasts of $\rho = 1$, $q \cdot 100\%$ of the time, and $\rho = 0$ the rest. This probability framework closely follows that developed in Winkler, Murphy, and Katz.

To calculate the value of improved information requires a recalculation of VI for a new probability distribution of ρ. The value of improved information is the difference between VI under the old distribution and VI under the new distribution. The difference measures the change in an industry's willingness to pay for weather information given that the industry currently is basing its decisions on historical weather probabilities. Because q is invariant to the probability distribution of ρ, it is sufficient to look at how expected profits of the information user change to gauge how the value of information changes as forecast accuracy increases (assuming that the forecasts remain correct).

The large number of possible values of ρ hampers a general qualitative exploration of the effects of increases in forecast accuracy. Restricting the number of possible forecasts increases the tractability of the problem. The remainder of the paper will focus on the effects of weather information assuming that there are only two possible values for ρ. With probability c, $\rho = \rho_g$, and with probability $1 - c$, $\rho = 1 - \rho_b$.[2] A further restriction is placed on the relationship between ρ_g and ρ_b by the assumption that $\Sigma\rho g(\rho) = q$. The restriction is that

$$(4)\quad \rho_b = \frac{1-c-q}{1-c} + \frac{c}{1-c}\rho_g.$$

Increases in forecast accuracy can be obtained by either increasing ρ_g or ρ_b. Assuming that c is held constant as forecast accuracy increases implies that for a given increase in ρ_g, a corresponding increase in ρ_b is defined by (4).

The value of weather information can now be written as

$$(5)\quad VI = c[\rho_g\pi(x_g, w_g) + (1-\rho_g)\pi(x_g, w_b)] + (1-c)[\rho_b\pi(x_b, w_b) + (1-\rho_b)\pi(x_b, w_g)] - q\pi(x_h, w_g) - (1-q)\pi(x_h, w_b),$$

where x_g and x_b are the optimal levels of x under the two values of ρ (ρ_g and $1 - \rho_b$).

Effects of an Increase in Forecast Accuracy

The value of information as defined in (5) is a function of forecast accuracy, which is represented by ρ_g. Because by (4), ρ_b is a function of ρ_g, changes in ρ_g affect both x_g and x_b. Differentiating the first-order condition (2) with respect to x and ρ (replacing ρ with its appropriate value) determines how input use changes as the forecasts become more accurate.

$$(6)\quad \frac{\partial x_g}{\partial \rho_g} = \frac{P[f(x_g, w_g)]f_x(x_g, w_g) - P[f(x_g, w_b)]f_x(x_g, w_b)}{-H_g},$$

$$(7)\quad \frac{\partial x_b}{\partial \rho_b} = \frac{P[f(x_b, w_b)]f_x(x_b, w_b) - P[f(x_b, w_g)]f_x(x_b, w_g)}{-H_b},$$

where H_g and H_b are the derivatives of (2) with respect to x_g and x_b. If demand is not upward sloping and if f is concave in x, both H_g and H_b are strictly negative.

How input demand changes as weather forecasts become more accurate depends on the relative magnitudes of output price and the mar-

[2] A forecast of $\rho = \rho_g$ can be considered a forecast of good weather. A forecast of $1 - \rho_b$ implies that the probability of w_b occurring equals ρ_b, so it can be considered a forecast of bad weather. Here good and bad weather refer only to output effects of weather.

ginal product of x under each of the weather states. By assumption, for a given level of x, $P[f(x, w_g)] < P[f(x, w_b)]$. Inputs x and w will be defined as production substitutes if $f_x(x, w_g) < f_x(x, w_b)$ and production complements if $f_x(x, w_g) > f_x(x, w_b)$.

Equation (6) can be unambiguously signed only when x and w are substitutes. When this occurs, both $P[f(x_g, w_g)] < P[f(x_g, w_b)]$ and $f_x(x_g, w_g) < f_x(x_g, w_b)$, so (6) is negative. When x and w are complements, the second inequality is reversed and (6) cannot be definitely signed. The condition for signing (7) is the same. When x and w are substitutes, $P[f(x_b, w_b)] > P[f(x_b, w_g)]$, $f_x(x_b, w_b) > f_x(x_b, w_g)$, and (7) is positive. Complementarity between x and w reverses the last inequality and the sign of (7) becomes indeterminant.

Signing (6) and (7) with complementarity between x and w depends on the responsiveness of output price to changes in supply and the degree to which the slope of the marginal product function of x is changed by weather. With a perfectly elastic demand curve, (6) is positive and (7) is negative. But if demand is quite inelastic, the negative price effects when good weather occurs are more likely to outweigh the positive productivity effects. The functional forms of the production and demand functions play a central role in determining how input use and supply change as weather forecasts become more accurate.

An exploration of necessary and sufficient conditions needed to sign the input, supply, and profit changes coming from improved weather information when w and x are complements proved quite fruitless. Instead, particular function forms are used to sign the effects. The forms used here assume that weather affects supply multiplicatively and that the demand function has constant elasticity. Let

$$(8) \qquad f(x, w) = g(x)T(w) \; w = w_g \text{ or } w_b,$$

where $g_x > 0$ and $T(w_g) > T(w_b)$, represent the case of production complements. To focus on the elasticity of demand let

$$(9) \qquad P[f(x, w)] = [f(x, w)]^{-\alpha},$$

where $\alpha > 0$. The (constant) elasticity of demand is $-\alpha^{-1}$. Using these functional forms, (6) and (7) become

$$(10) \qquad \frac{\partial x_g}{\partial \rho_g} = \frac{-g_x}{g_{xx} - \alpha g^{-1} g_x^2} \cdot \frac{T(w_g)^{1-\alpha} - T(w_b)^{1-\alpha}}{\rho_g T(w_g)^{1-\alpha} + (1 - \rho_g)T(w_b)^{1-\alpha}},$$

$$(11) \qquad \frac{\partial x_b}{\partial \rho_b} = \frac{-g_x}{g_{xx} - \alpha g^{-1} g_x^2} \cdot \frac{T(w_b)^{1-\alpha} - T(w_g)^{1-\alpha}}{\rho_b T(w_b)^{1-\alpha} + (1 - \rho_b)T(w_g)^{1-\alpha}}.$$

Given that $g_{xx} < 0$, the signs of (10) and (11) are determined by the value of α. When $\alpha < 1$ (i.e., demand is elastic)

$$T(w_g)^{1-\alpha} - T(w_b)^{1-\alpha} > 0,$$

which implies that

$$\frac{\partial x_g}{\partial \rho_g} > 0 \text{ and } \frac{\partial x_b}{\partial \rho_b} < 0.$$

The signs are reversed if demand is inelastic.

Rewriting (5) as

$$VI = cE_g(\pi) + (1 - c)E_b(\pi) - E_h(\pi),$$

where the subscript on the expectations operator denotes the weather distribution used to maximize expected profits, shows clearly how to determine the marginal value of weather information as the information becomes more accurate. As noted above, changes in forecast accuracy do not change the *ex ante* expected profits of the farmer who does not use the information. The marginal value of better weather information, therefore, can be written as

$$(12) \qquad \frac{\partial VI}{\partial \rho_g} = c\frac{\partial E_g(\pi)}{\partial \rho_g} + (1 - c)\frac{\partial E_b(\pi)}{\partial \rho_b}\frac{\partial \rho_b}{\partial \rho_g} = c\left\{\frac{\partial E_g(\pi)}{\partial \rho_g} + \frac{\partial E_b(\pi)}{\partial \rho_b}\right\}.$$

Applying the envelope theorem to the partial derivatives of the two profit functions results in

$$(13) \qquad \frac{\partial E_g(\pi)}{\partial \rho_g} = P[f(x_g, w_g)]f(x_g, w_g) - P[f(x_g, w_b)]f(x_g, w_b) + [\rho_g f(x_g, w_g)P'[f(x_g, w_g)]f_x(x_g, w_g) + (1 - \rho_g)f(x_g, w_b)P'[f(x_g, w_b)]f_x(x_g, w_b)]\frac{\partial x_g}{\partial \rho_g},$$

$$(14)\qquad \frac{\partial E_b(\pi)}{\partial \rho_b} = P[f(x_b, w_b)]f(x_b, w_b) - P[f(x_b, w_g)]f(x_b, w_g) + [\rho_b f(x_b, w_b)P'[f(x_b, w_b)]f_x(x_b, w_b) + (1 - \rho_b)f(x_b, w_g)P'[f(x_b, w_g)]f_x(x_b, w_g)]\frac{\partial x_b}{\partial \rho_b}.$$

Determining the signs of (13) and (14) is straightforward. The first terms in the two expressions measure the expected profit effects from a change in expected weather.[3] When demand is elastic (inelastic), revenue in the high output, low price state is greater (less) than the revenue in the low output, high price state. The second term measures the impacts on expected profits from the expected price change brought about by a different input use. Because demand is downward sloping, the sign of this effect is opposite the sign of the change in input use.

When demand is elastic and x and w are substitutes, (13) is positive and (14) is negative. The two effects work in the same direction for each equation. However, when demand is inelastic the signs cannot be determined unambiguously by simple inspection.

When x and w are complements and the two functional forms in (8) and (9) are appropriate, some algebraic manipulations and the substitution of (10) and (11) result in

$$(15)\qquad \frac{\partial E_g(\pi)}{\partial \rho_g} = \frac{g^{1-\alpha}g_{xx}}{g_{xx} - \alpha g^{-1}g_x^2}[T(w_g)^{1-\alpha} - T(w_b)^{1-\alpha}]$$

$$(16)\qquad \frac{\partial E_b(\pi)}{\partial \rho_b} = \frac{g^{1-\alpha}g_{xx}}{g_{xx} - \alpha g^{-1}g_x^2}[T(w_b)^{1-\alpha} - T(w_g)^{1-\alpha}].$$

When demand is elastic ($\alpha < 1$), $T(w_g)^{1-\alpha} > T(w_b)^{1-\alpha}$, so (15) is positive and (16) is negative. The signs are reversed when demand is inelastic.

To sign (12) requires additional knowledge about the relative magnitudes of x_g and x_b. This is true even with the more restrictive functional forms used to examine the changes when x and w are complements. To indicate what factors determine the sign of (12) when increases in w increase the marginal product of x, let $g(x)$ be a Cobb-Douglas function. That is, let

$$(17)\qquad f(x, w) = Ax^{\beta} \cdot T(w)\ w = w_g \text{ or } w_b,$$

with $T(w_g) > T(w_b)$. The remainder of the paper will utilize this particular functional form.

Changes in the Value of Information

Using (17), (12) becomes

$$(18)\qquad \frac{\partial VI}{\partial \rho_g} = \frac{c(1-\beta)}{1-\beta(1-\alpha)}[T(w_g)^{1-\alpha} - T(w_b)^{1-\alpha}][g(x_g)^{1-\alpha} - g(x_b)^{1-\alpha}].$$

The sign of (18) depends on the relative magnitudes of x_g and x_b and on the elasticity of demand. The solutions to the first-order conditions with the production function in (17) are

$$(19)\qquad x_g = K[\rho_g T(w_g)^{1-\alpha} + (1-\rho_g)T(w_b)^{1-\alpha}]^{1/1-\beta(1-\alpha)}, \text{ and}$$

$$(20)\qquad x_b = K[\rho_b T(w_b)^{1-\alpha} + (1-\rho_b)T(w_g)^{1-\alpha}]^{1/1-\beta(1-\alpha)},$$

where

$$K = \left[\frac{\beta A^{1-\alpha}}{P_x}\right]^{1/1-\beta(1-\alpha)}.$$

The size of x_g relative to x_b is determined by the relative magnitudes of the two bracketed terms in (19) and (20) because $1 - \beta(1-\alpha) > 0$. Noting that $\rho_g + \rho_b - 1 > 0$, which is the same as $\rho_g > q$ [see expression (4)], some straightforward algebra shows that the bracketed term in (19) is greater (less) than its (20) counterpart when demand is elastic (inelastic). Thus, $x_g > x_b$ when demand is elastic, and $x_g < x_b$ when demand is inelastic.

If demand is elastic, $g(x_g) > g(x_b)$, $g(x_g)^{1-\alpha} > g(x_b)^{1-\alpha}$, and $T(w_g)^{1-\alpha} > T(w_b)^{1-\alpha}$, which implies that the marginal value of information increases with an increase in forecast accuracy.

[3] At first glance, one would think that the sum of the first two terms in expressions (13) and (14) must equal zero since the long-run or historical frequency of weather has not changed. But what has changed are the conditional probabilities of supply and price under each weather state. For example, given that w_g occurs, it is more likely that x_g will have been applied with an increase in ρ_g. Thus, with an elastic demand, expected supply, given that w_g occurs, increases. Similarly, it is more likely that x_b will have been applied when w_b occurs, so expected supply given w_b drops. The net effect is positive because, with x and w being complements, more output will be forthcoming in weather state w_g than is lost in w_b.

But, when demand is inelastic, the marginal value is negative. In this case, $T(w_g)^{1-\alpha} < T(w_b)^{1-\alpha}$, but because $x_g < x_b$, $g(x_g)^{1-\alpha}$ remains greater than $g(x_b)^{1-\alpha}$.

The decline in the value of weather information as information becomes more accurate appears to be a counterintuitive result. That is, it appears to violate the principle of optimality in which an action would not be taken if an individual is made worse off by the action. The argument here is different. Each farmer acts optimally by fully utilizing the weather information. Ignoring the information when all other farmers are using it would make a farmer worse off. Therefore, the value of improved information to an individual farmer is positive. The total industry may be worse off with better information because of negative price effects. If the industry could collectively decide on a position about the possibility of improving the accuracy of weather information, the decision would be to not make the improvement.

The result that agricultural producers facing an inelastic demand can be made worse off from better information is similar to the finding that average farmers who are forced to ride the technological treadmill by adopting new technologies can be made worse off (Wilcox and Cochrane). But, whereas this argument relies on a supply expansion to lower profits, it can be shown that aggregate farmer profits can decrease even when average supply decreases.

Changes in Input Use

First, consider how the average use of x changes as the weather forecast becomes more accurate. Define average use of x as

$$\bar{x} = cx_g + (1 - c)x_b.$$

The change in average use of x due to an increase in ρ_g then is written,

$$(21)\qquad \frac{\partial \bar{x}}{\partial \rho_g} = c\left\{\frac{\partial x_g}{\partial \rho_g} + \frac{\partial x_b}{\partial \rho_b}\right\}.$$

With x_g and x_b given by (19) and (20), expression (21) becomes

$$(22)\qquad \frac{\partial \bar{x}}{\partial \rho_g} = \frac{cK}{1 - \beta(1 - \alpha)}[T(w_g)^{1-\alpha} - T(w_b)^{1-\alpha}][R_1^{\phi} - R_2^{\phi}],$$

where $R_1 = \rho_g T(w_g)^{1-\alpha} + (1 - \rho_g)T(w_b)^{1-\alpha}$, $R_2 = \rho_b T(w_b)^{1-\alpha} + (1 - \rho_b)T(w_g)^{1-\alpha}$, and $\phi = \beta(1 - \alpha)/(1 - \beta(1 - \alpha))$, and K is as defined in (19). The first bracketed term in (22) is positive (negative) when demand is elastic (inelastic). The second bracketed term is always positive because an elastic demand makes $R_1 > R_2$ and $\phi > 0$, while an inelastic demand makes $R_1 < R_2$ and $\phi < 0$. Thus, with an elastic demand curve, average use of x increases with increases in forecast accuracy. In contrast, average use of x declines if demand is inelastic. The latter case illustrates that more accurate weather forecasts can signal farmers that, on average, it is more profitable to use less of the supply-increasing input. The consequences of this signal on expected supply are shown next.

Changes in Expected Supply

Expected supply is given by

$$E(y) = cg(x_g)[\rho_g T(w_g) + (1 - \rho_g)T(w_b)] + (1 - c)g(x_b)[\rho_b T(w_b) + (1 - \rho_b)T(w_g)].$$

An increase in forecast accuracy can be evaluated by differentiating expected supply with respect to ρ_g, which with $g(x)$ specified as Cobb-Douglas results in

$$(23)\qquad \frac{\partial E(y)}{\partial \rho_g} = c[g(x_g) - g(x_b)][(T(w_g) - T(w_b)] + cK_2\left[g(x_g)\frac{\rho_g T(w_g) + (1 - \rho_g)T(w_b)}{\rho_g T(w_g)^{1-\alpha} + (1 - \rho_g)T(w_b)^{1-\alpha}} - g(x_b)\frac{\rho_b T(w_b) + (1 - \rho_b)T(w_g)}{\rho_b T(w_b)^{1-\alpha} + (1 - \rho_b)T(w_g)^{1-\alpha}}\right],$$

where

$$K_2 = \frac{c\beta}{1 - \beta(1 - \alpha)} A\left[\frac{\beta A^{1-\alpha}}{P_x}\right]^{\beta/1-\beta(1-\alpha)} \cdot [T(w_g)^{1-\alpha} - T(w_b)^{1-\alpha}].$$

The sign of (23) is not immediately apparent. It can be shown, however, (see the appendix) that when demand is inelastic, (23) is negative. Moreover, a sufficient condition for expected

supply to increase when demand is elastic is $\beta(2 - \alpha) - 1 > 0$.

A Numerical Example

The intuition behind the qualitative results developed above can be obtained with the use of a simple numerical example. Assume that $\rho_g = \rho_b$, $c = q = 0.5$, and $T(w) = 1 + w$, with $w_g = .2$, and $w_b = -.2$. The Cobb-Douglas portion of the production function is defined by setting $\beta = 0.5$ and $A = 2$. With this model specification, the calculated changes in *ex ante* expected profits, output, price, and input use as ρ increases from .5 (no information) to unity (perfect information) for both an elastic and an inelastic demand are presented in table 1. Demand is given by expression (9). Average use of x, expected supply, and expected profits all increase (decrease) as forecast accuracy increases when demand is elastic (inelastic). The response of expected profits is seen by noting that expected price also increases (decreases) as forecast accuracy increases when demand is elastic (inelastic).

To see what drives these results, refer to table 2, which reports the input levels and corresponding output levels under the two weather forecasts and the two weather states. Also reported in table 2 are expected output levels conditional on weather for the two demand elasticities. Conditional expected output is $E(y|w = w_g) = \rho f(x_g, w_g) + (1 - \rho)f(x_b, w_g)$, under w_g, and $E(y|w = w_b) = \rho f(x_b, w_b) + (1 - \rho)f(x_g, w_b)$, under w_b where $f(\cdot)$ denotes the production function. When $\rho = .5$, $x_g = x_b$, and the only variability in output is due to weather variation, which implies that $E(y|w = w_g) = f(x_g, w_g)$. When $\rho = 1$, there is no weather uncertainty, and again, $E(y|w = w_g) = f(x_g, w_g)$ because the probability associated with $f(x_b, w_g)$ is zero. Similarly, $E(y|w$

Table 1. Unconditional Expected Effects of Weather Information

	Demand Elasticity							
	−5.0				−0.5			
Forecast accuracy (ρ)	0.5	0.7	0.9	1.0	0.5	0.7	0.9	1.0
Input use ($E(x)$)	4.580	4.591	4.622	4.646	1.893	1.891	1.887	1.884
Supply ($E(y)$)	2.140	2.149	2.174	2.194	1.375	1.372	1.360	1.351
Price ($E(P)$)	0.863	0.864	0.865	0.866	0.596	0.593	0.585	0.578
Profits ($E(\pi)$)	0.916	0.918	0.924	0.929	0.379	0.378	0.377	0.376

Table 2. Conditional Effects on Input and Output Levels of Weather Information

Weather Forecast	Good Weather[a]				Bad Weather			
				Demand Elasticity = −5.0				
Forecast accuracy (ρ)	0.5	0.7	0.9	1.0	0.5	0.7	0.9	1.0
Input use	4.58	5.08	5.60	5.87	4.58	4.10	3.64	3.42
Realized output under								
good weather	2.57	2.71	2.84	2.91	2.57	2.43	2.29	2.22
bad weather	1.71	1.80	1.89	1.91	1.71	1.62	1.53	1.48
Expected output given								
good weather	2.57	2.63	2.79	2.91				
bad weather	1.71	1.67	1.57	1.48				
				Demand Elasticity = −0.5				
Input use	1.89	1.79	1.69	1.63	1.89	1.99	2.09	2.14
Realized output under								
good weather	1.65	1.61	1.56	1.53	1.65	1.69	1.73	1.75
bad weather	1.10	1.07	1.04	1.02	1.10	1.13	1.16	1.17
Expected output given								
good weather	1.65	1.63	1.57	1.53				
bad weather	1.10	1.11	1.15	1.17				

[a] Good weather is represented by w_g, and bad weather is represented by w_b. A forecast of good weather occurs when $\Pr(w = w_g) = \rho$. A forecast of bad weather occurs when $\Pr(w = w_g) = 1 - \rho$.

$= w_b) = f(x_b, w_b)$ under the two information extremes.

The implications of the behavior of these conditional output expectations can be seen in figure 1, which depicts the unconditional expected output and price for $\rho = .5$ and unity under an inelastic demand. In figure 1, y_g^p denotes output under perfect information and good weather; y_g^n, output under no information and good weather; y_b^p, output under perfect information and bad weather; and y_b^n, output under no information and bad weather. Furthermore, let P_g^p, P_g^n, P_b^p, and P_b^n denote the corresponding prices. Under the assumption that $q = 0.5$ (the two weather states have an equal chance of occurring), unconditional expected price and output are found by bisecting the rays connecting the two output/price pairs under each of the two weather information extremes. As shown in figure 1, as ρ increases from 0.5 to unity, expected output decreases from $E^n(y)$ to $E^p(y)$ and expected price decreases from $E^n(P)$ to $E^p(P)$.[4] Unconditional expected revenue declines because both expected output and expected price decrease. This decline more than offsets the decrease in expected cost, hence expected profits decline.[5]

[4] It can be shown that the relationship between $E(y|w)$ and ρ is monotonic for both weather states. Thus, the situation depicted in figure 1 holds for all values of ρ if, in figure 1, $E(y|w = w_g)$ replaces y_g^i and $E(y|w = w_b)$ replaces y_b^i, $i = p$ or n.

[5] The results reported in table 2 also illustrate the relationship between demand elasticity and supply variability. With an inelastic demand improvements in information reduce output variability. Farmers produce less when they are more confident that good weather is forthcoming and more when they are more confident that bad weather is forthcoming. With an elastic demand increases in forecast accuracy increase output variability because farmers are primarily concerned with the physical productivity effects of weather rather than the price effects. Thus, even though improvements in forecast accuracy decrease uncertainty, supply and price variability may increase.

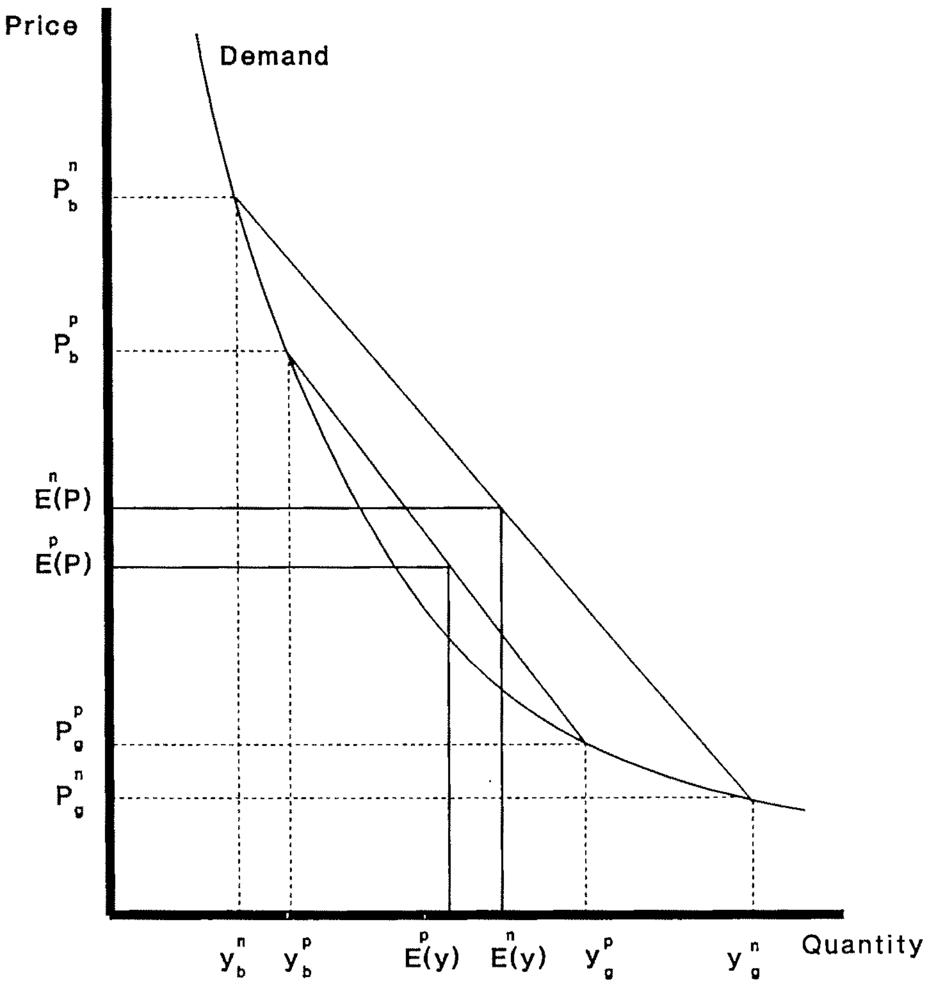

Figure 1. The supply and price effects from improved weather forecasts with an inelastic demand

Other simulation results involving a quadratic production function and a linear demand curve give further insight into the use of weather information. There were two major differences between those results and the ones reported here. First, the physical productivity effects of weather information always dominated the price effects: when good weather was forecast more accurately, more of the supply-increasing input was used; when bad weather was forecast more accurately, less of the input was used. The net effect was that expected supply increased for both inelastic and elastic demands. The second difference was that expected price and expected supply moved in opposite directions because of the restrictions imposed by the linear demand curve. Therefore, with an inelastic demand, the expected supply increase from improved weather forecasts resulted in lower total revenue, which, when combined with higher costs, meant that expected profits decreased with improvements in weather forecasts. With an elastic demand, the expected supply increase caused total revenues to increase, which more than dominated the increase in cost. Thus, the basic result that better weather information can lead to lower producer welfare is not dependent on the functional forms used here. However, the changes in input use and expected supply from better weather information are much more dependent on the particular interactions between weather variables and the marginal products of production factors.

Concluding Comments

Information is generally considered to be a supply-increasing production input and welfare increasing to producers. The argument is that producers would not use information if it did not make them better off. These two well-accepted characterizations are valid if there are no price effects from the use of the information.

Optimal input use is not only a function of physical productivity, it also depends on prices. If information signals farmers that prices will be much lower, for example, then it may be optimal to reduce the use of production factors. Price changes can also influence the value of information. The definitional truism that information is welfare increasing presumes no external effects from the use of information. One source of possible external effect is from prices. Information about the productivity of input decisions will influence prices if enough producers utilize the information to make their supply decisions. Competitive farmers have no control over prices. This lack of control creates a price externality: the aggregate effects of farmers' actions change prices, but individual farmers are too small to have a significant effect; hence, the marginal price effects are not taken into account when production decisions are made.

This paper examines an agricultural industry with many identical producers, all of whom control supply with a single variable production input. From this model, it is shown that the role of information in a production system can be quite different than is generally considered. Lave's result that producers can be made worse off from better weather information is shown to be true even when farmers know that their collective action is making them worse off. Moreover, market price effects from information can dominate physical productivity effects, particularly when demand is inelastic. When this occurs, information is a supply-decreasing production input: more accurate information signals farmers that it is more profitable for them to produce less, not more.

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Calibration of Option-Based Probability Assessments in Agricultural Commodity Markets

Paul L. Fackler and Robert P. King

A method for evaluating the reliability of option-based price probability assessments is developed based on the calibration concept. Empirical tests using goodness-of-fit criteria are applied to four agricultural commodities. Results suggest that assessments in the corn and live cattle markets are reliable, but such assessments overstate the volatility of soybean prices and understate the location of hog prices.

Key words: calibration, futures, goodness-of-fit, options, probability assessment.

The initiation of trading on agricultural commodity option futures in 1984 created new risk management opportunities for market participants. This expansion in risk management alternatives directly benefits only those who trade options. As Gardner notes, however, commodity option markets can also provide useful public information about price probability distributions. Probability assessments derived from data on option premiums require only a limited amount of readily available information and can be updated easily.

For decision makers, the performance of option-based price probability assessments is an important issue. This paper focuses on one aspect of their performance: calibration or reliability (DeGroot and Fienberg; Winkler; Lichtenstein, Fischoff, and Phillips). A probability assessment method is well calibrated "if, over the long run, for all propositions assigned a given probability, the proportion that is true equals the probability assigned" (Lichtenstein, Fischoff, and Phillips, p. 307).

Calibration is important for two reasons. First, well-calibrated probability assessment methods generate reliable probability statements. Second, well-calibrated option-based probability assessments are consistent with the absence of risk premiums in options markets. Therefore, tests for calibration provide useful information about the functioning of option markets.

In the sections to follow, a theory of option pricing based on the absence of arbitrage opportunities is outlined and results from that theory are used to show how probability assessments can be derived from option premiums. The concept of calibration is then defined and statistical methods for testing the calibration of option-based probability assessments are described and used to evaluate the performance of price probability assessments for corn, soybeans, live cattle, and hogs. Implications of the findings and needs for further research are found in the concluding section.

Option Pricing Theory

Option contracts guarantee their holder the right to buy or sell a specified asset (the underlying asset) at a given price (the exercise price) on or before a given date (the expiration date). Put and call options provide the right to sell and to buy, respectively. European options allow exercise of the option only on the expiration date, while American options allow exercise any time on or before that date. An option premium is the price paid for the option contract; typically, it is payable immediately and in full.

A general theory of option pricing, based on Cox and Ross, relies on the minimal assumption that no arbitrage opportunities exist. They show that this condition is equivalent to the existence of an artificial probability distribution such that the asset price equals the stream of expected re-

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turns discounted at the risk-free rate. The idea of an artificial distribution is widely applied in the finance literature. It is called the risk-neutral valuation measure (RNVM) in this paper.

To apply this notion to the pricing of options, note that the return to a European put option with exercise price x expiring at time T (the expiration date) is $\max(0, x - Y_T)$, where Y_T is the (random) price of the underlying asset at time T. If arbitrage opportunities are absent, the current price of the option, $V_p(x)$, can be written as

$$(1) \quad V_p(x) = b(T) \int_0^\infty \max(0, x - Y_T)\, dG(Y_t),$$

where $b(T)$ is the current price of a risk-free pure discount bond paying \$1 at time T, and G is the RNVM discussed above. This expression can be rearranged as

$$(2) \qquad V_p(x) = b(T)\{xG(x) - E_G[Y_T; x]\},$$

where

$$E_G[Y_T; x] = \int_0^x Y_T\, dG(Y_T)$$

is the incomplete expectation of Y_T with respect to $G(Y_T)$.

Similarly, the value of a European call option can be written as

$$\begin{aligned}(3) \quad V_c(x) &= b(T) \int_0^\infty \max(0, Y_T - x)\, dG(Y_T), \\ &= b(T)\{E_G[Y_T] - E_G[Y_T; x] \\ &\quad - x(1 - G(x))\}, \\ &= V_p(x) + b(T)\{E_G[Y_T] - x\}.\end{aligned}$$

This approach can also be used to show that the current value of an asset paying $Y_T/b(T)$ at time T is equal to y_0, the current futures price (Cox, Ingersoll, and Ross). Therefore,

$$\begin{aligned}(4) \qquad y_0 &= b(T) \int_0^\infty Y_T/b(T)\, dG(Y_T) \\ &= E_G[Y_T].\end{aligned}$$

Combining (3) and (4) yields the familiar put-call parity relationship for options on futures:

$$(5) \qquad V_c(x) - V_p(x) = b(T)(y_0 - x).$$

Given $G(Y_T)$, the value of an option can be defined. For example, if $G(Y_T)$ is log-normal with mean μ and standard deviation σ, then[1]

$$\begin{aligned}(6) \qquad V_p(x) = b(T)\{&x\Phi((z + \sigma/2) \\ &- y_0\Phi((z - \sigma/2)\},\end{aligned}$$

where $z = \ln(x/y_0)/\sigma$, and, given the symmetry of the normal distribution,

$$\begin{aligned}(7) \qquad V_c(x) = b(T)\{&y_0\Phi((z + \sigma/2) \\ &- x\Phi((z - \sigma/2)\}.\end{aligned}$$

These formulas are equivalent to the familiar option pricing formulas derived by Black (p. 177) and Gardner (p. 989).[2]

Option-Based Probability Assessments

Knowledge of the RNVM, $G(Y_T)$, which need not be log-normal, and the price of a risk-free bond, $b(T)$, is sufficient to calculate the premiums for call or put options at any exercise price. Conversely, knowledge of option premiums [and $b(T)$] can be used to infer information about $G(Y_T)$ (Breeden and Litzenberger). Suppose that $G(Y_T)$ can be reasonably well approximated by a parametric family of functions. The particular member of this family can be selected by finding the parameter values that yield predicted option premiums closest to observed market premiums.

In this study $G(Y_T)$ is assumed log-normal to simplify the analysis and facilitate comparison with other studies. A preliminary analysis using a more flexible distribution, the Burr-12 or Singh-Madalla (Singh and Madalla, McDonald), did not greatly improve the fit between predicted and actual option premiums. Under log-normality, the option valuation formulas in equations (6) and (7) have only one unobserved parameter, σ. Given an observed option premium, a value of σ can be found that yields a predicted premium exactly equal to the observed value.[3] The re-

[1]These formulas make use of the following facts (Hogg and Klugman, p. 229):

$$\begin{aligned}G(x) &= \Phi((\ln(x) - \mu)/\sigma), \\ E_G[Y_T] &= \exp(\mu + \sigma/2), \text{ and} \\ E_G[Y_T; x] &= E_G[Y_T]\Phi((\ln(x) - \mu)/\sigma - \sigma),\end{aligned}$$

where Φ is the standard normal CDF.

[2]A superficial difference between the formulas involves the $sqrt(T)$ term in Black's formulation. This difference is explained by the fact that the variance term, σ^2, used in this paper refers to the variance parameter associated with the expiration date price, which is T times the daily variance used by Black.

[3]Computationally, this involves a numerical search algorithm because no analytical solution exists. The bisection method was used in this study because it is easy to implement and reasonably fast. The evaluation of the option values also requires the numerical evaluation of the standard normal CDF. See Kennedy and Gentle (pp. 90–93) for a discussion of numerical techniques for this problem.

sulting value of σ is commonly termed the implied volatility. It is uniquely determined by the option premium, given its exercise price, the current futures price, the price of an appropriate risk-free bond, and the time until expiration, and has been used in a number of studies (e.g., Latané and Rendleman, Chiras and Manaster, Schmalensee and Trippi, Beckers).

Options typically are traded at a number of different exercise prices. Several implied volatility estimates, therefore, can be calculated for any given trading period. Options with exercise prices that are not close to the asset's current price tend to be thinly traded; thus, they may nor accurately reflect equilibrium relationships. The just-out-of-the-money option is usually the most heavily traded and is used in this study. Both the just-out put and just-out call were used to calculate implied volatilities, and the two volatility estimates were then averaged.

Given an estimate of σ the implied value of μ is given by

$$(8) \qquad \mu = \ln(y_0) - \sigma^2/2.$$

Parameters μ and σ provide a complete description of the RNVM, $G(Y_T)$.

The example in table 1 illustrates the process for generating probability assessments. The data come from the *Wall Street Journal* and include the current and expiration date futures prices, y_0 and Y_T, the just-out put and call premiums and their strike prices and the bid and ask discount rates on the appropriate T-bill. In this example, there are eight weeks (56 days) remaining until expiration. The bid and ask bond rates are combined to obtain an average rate, r, from which the bond price is calculated using $b = 1 - r*56/360$. The implied volatilities using the put and

Table 1. An Example of the Data and Calculation of the Log-Normal *RNVM*

Contract	November 1985 Soybeans
Current date	16 August 1985
Expiration date	11 October 1985
Current futures (y_0)	513.5
500 put	8.625
525 call	9.25
T-bill bid rate	7.09
T-bill ask rate	7.05
Average T-bill rate	7.07
Bond price (b)	0.989
Implied volatility from put	0.07165
Implied volatility from call	0.06942
Average implied volatility (σ)	0.07053
Implied mean (μ)	6.23876

call contracts are calculated numerically as the solution to (6) and (7). The average of these volatilities yields the implied volatility measure, σ. The "implied mean," μ, is calculated from (8).

The relationship between the artificial probability distributions generated by this process and the actual stochastic behavior of associated expiration date futures prices is an important empirical stochastic issue. If the G's reliably represent the stochasitc behavior of the associated Y_T's (i.e., if the G's are well calibrated), option-based probability assessments are a reliable, readily available source of probabilistic information. Furthermore, if the G's are well calibrated, equations (2) and (3) imply that option premiums equal the present value of the expected returns and are, therefore, an actuarially fair form of price insurance.

Generally, little can be said theoretically about the relationship between G and the stochastic behavior of Y_T. However, poor calibration of G can be identified for several reasons. First, if option writers require risk premiums because they cannot diversify away the risk of an options position, then the value of the option would be greater than under risk-neutral conditions. If G is log-normal, this condition would result in upward bias in the implied volatility. Second, risk premiums may be required by speculators in the underlying futures (see Kamara for a review). For example, if normal backwardation exists ($y_0 < E[Y_T]$), the location of G would be biased downward. Third, G may be unreliable because probability assessments of market participants are unreliable. None of these factors affect the validity of the RNVM approach to pricing options; instead, they affect the relationship between the RNVM and an objective stochastic measure of price behavior.

Poor calibration may also reflect problems with the construction of the RNVM rather than the nature of the market. For example, equations (6) and (7) strictly apply only to European options, while the options traded in the United States are American options. Failure to consider that American options are more valuable than their European counterparts (Ramaswamy and Sundaresan) could cause an upward bias in the implied volatility. However, after calculating values for both American- and European-type options, Plato concluded (p. 9) that the difference between the two for near-the-money option values is negligible. Methodological problems may also be caused by nonsynchronous option and futures prices and prices that represent nontrades, though this problem is minimized by the use of heavily traded options.

This study does not attempt to explain lack of calibration in option-based probability assessments. Rather, the goals are to examine whether such assessments are well calibrated, to describe any calibration problems, and to suggest how the assessments can be improved. The derivation of these probability forecasts is purposely simplified by not considering all possible sources of poor calibration.

The Concept of Calibration

Approximations of the RNVF derived from option premiums will not necessarily generate reliable probability statements for the expiration date futures price. An empirical examination of this issue is based on the concepts of calibration and the calibration function (Bunn, chap. 8).

To make the calibration concept more explicit, let G_i for $i = 1, \ldots, n$ be a set of probability assessments, expressed as CDFs, for a set of realizations of a random variable, Z. Given a large sample of independent assessments, G_i, and realized outcomes of Z, z_i, the probability assessment process generating the G_i is calibrated if the proportion of times $G_i(z_i)$ is less than or equal to any given value, u, on the interval [0, 1] is u. More formally, let U be a random variable on the interval [0, 1] with CDF $C(U)$, defined by $U_i = G_i(Z_i)$. The process used to generate the G_i is calibrated if U is uniformly distributed on the interval [0, 1], i.e., if $C(u) = u$ for all u on the interval [0, 1].

In this study, option-based probability assessments are the G_i. For any option-based assessment, the realized outcome, z_i, is the expiration date price of the underlying futures contract, Y_T. Evaluating the G_i at Y_T generates a CDF value, a u_i. This is illustrated by the example in table 1. The realized price associated with the assessment (the expiration date futures price) is 502. The associated CDF value, the u_i, is calculated as

$$(9)\quad \begin{aligned} u_i &= \Phi((1\text{n}(Y_T) - \mu/\sigma) \\ &= \Phi((1\text{n}(502) - 6.23876)/0.07053) \\ &= 0.3875. \end{aligned}$$

If the option-based assessment process is well calibrated, the u_i calculated in this manner from a sample of independent assessments will be uniformly distributed.

The function C, the CDF of U, is called a calibration function (Bunn; for alternate terminology see Curtis, Ferrell, and Solomon; Morris). The calibration function provides a means of transforming a noncalibrated assessment into a calibrated one. The distribution defined by the transformation $F_i(Z) = C(G_i(Z))$ will always be a calibrated distribution because, for any Z,

$$(10)\quad \begin{aligned} C(G_i(z_i)) &= \text{Prob}(G_i(Z_i) \leq G_i(z_i)), \\ &= \text{Prob}(Z_i \leq z_i). \end{aligned}$$

When the G_i are calibrated, $F_i = G_i$. When the G_i are not calibrated, the calibration function can provide insights into the nature of the problems in assessment process and their resolution.

In the example in table 1 G_i is log-normal with parameters $(\mu, \sigma) = (6.239, 0.0705)$. Suppose, however, that the options-based volatility assessment is inflated because options writers require a substantial risk premium. More specifically, suppose that dividing the volatility parameter, σ, by 2 results in calibrated assessments, and therefore F_i is log-normal with parameters $(\mu, \sigma/2)$. The calibration function associated with this case is illustrated in the upper left-hand panel of figure 1. Because the assessed distributions tend to overstate variability, U_i is more likely to fall in the center of the distribution than in its tails, resulting in an S-shaped calibration function. The original G_i and the calibrated F_i are illustrated in the upper right-hand panel of figure 1. The function C serves to calibrate G_i by shifting probability weight from the tails to the center of the distribution, thus yielding a calibrated assessment with lower variance than the original assessment.

In a second example, shown in the lower panel of figure 1, the G_i's tend to understate the mean parameter, μ, by 0.01. Such a situation might reflect normal backwardation in the underlying futures. U_i is more likely to fall above 0.5 than below it, resulting in the "J-shaped" calibration function shown in the lower left-hand panel. In this case the calibration function calibrates G_i by shifting probability weight into the right-hand tail.

These examples illustrate how the calibration function is associated with specific kinds of probability assessment problems. A straight (45°) line indicates that no such problems exist. In general, flat spots in the calibration function (parts with slope less than one) are associated with areas of the assessed distribution that receive too much weight, while steep parts are associated with areas that receive too little weight. Overassessment of the volatility, for example, places too much weight in the tail areas of the assessed distribution. The calibration function must, there-

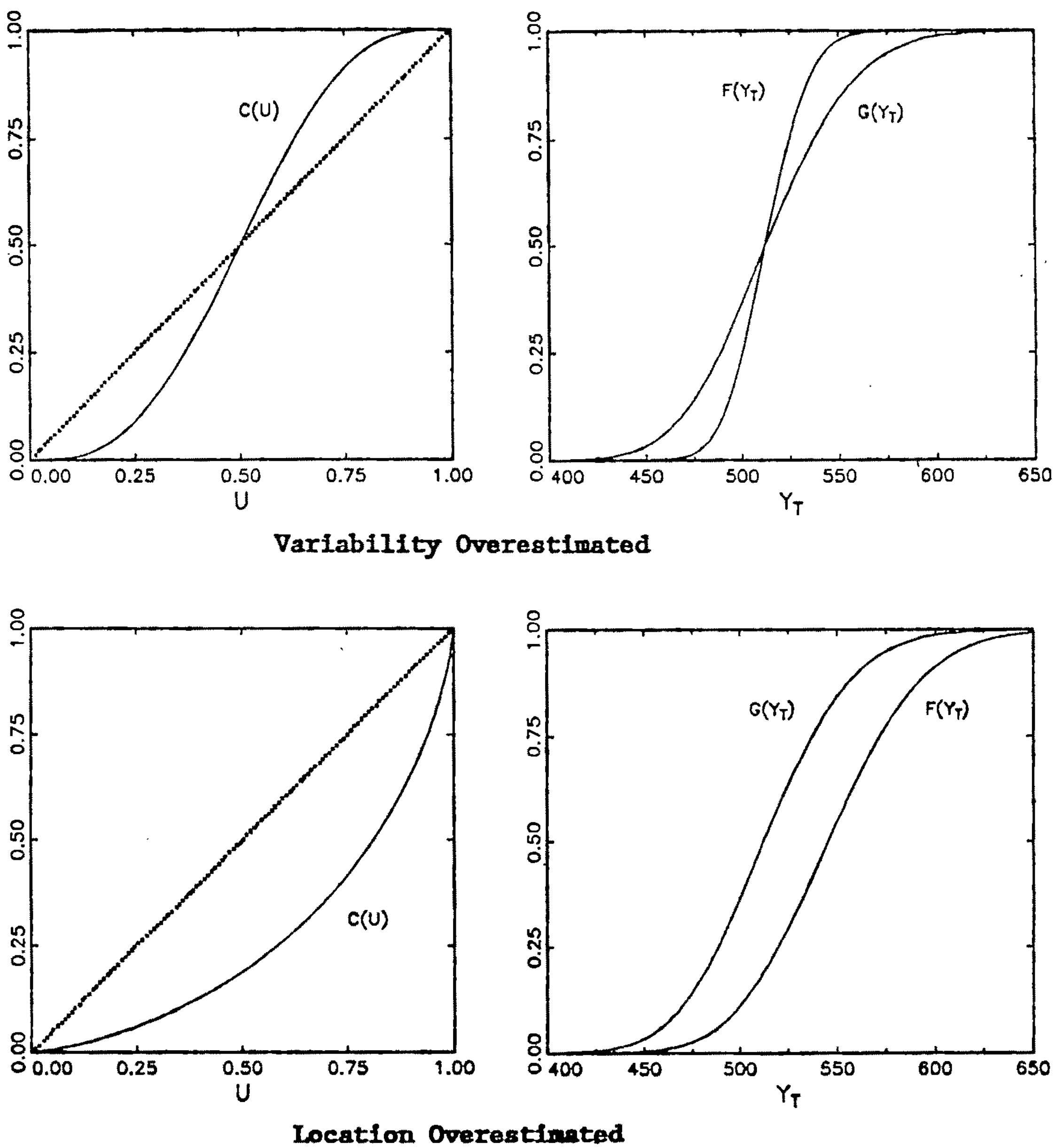

Figure 1. Examples of calibration functions: $F(Y_T) = C(G(Y_T)) = C(U)$

fore, be flat in the tails and steep in the center (S-shaped). If the assessed location is too far to the left, the calibration function must put more weight in the right tail and therefore will exhibit a flat-steep (J-shaped) pattern. Steep-flat-steep and steep-flat patterns are indicative of under-assessment of volatility and overassessment of location, respectively.

The value of the calibration function at 0.5 is a useful indictor of bias in location (median). If $C(0.5) < 0.5$ (> 0.5), more weight is in the right (left) half of the calibration function; hence, the assessed distribution is located too far to the left (right). A comparable indicator of problems in assessing dispersion is the range of the calibration function over the middle half of its domain (the interquartile range): $IQR = C(0.75) - C(0.25)$. An $IQR > 0.5$ (< 0.5) indicates that too few (many) observations fall in the tails of the assessed distribution.

Estimation of Calibration Functions

The calibration function associated with an assessment method can be estimated statistically given a random sample of values of U. A single observation on U provides no information on the reliability of an assessment process; a process can be evaluated only when patterns emerge in a sample of assessments. Furthermore, the U_t used to estimate a calibration function should be independent random variables. New option-based probability assessments can be constructed almost continuously; however, they will not necessarily yield independent U_t values because all assessments for a particular option contract share the same realized price. A random sample can be constructed by considering only one option-based assessment per futures contract and by ensuring that the time periods between trading and expiration dates do not overlap for any sample assessments.

The simplest estimator of C is the empirical CDF of a set of U_t values. After sorting the n-values of U_i in ascending order, the empirical CDF is obtained by setting $C(U_i) = i/n$. This procedure makes no assumption about the form of C. Alternatively, a parametric representation of C can be obtained by choosing a suitable functional form for C. The parametric approach offers both parsimony and ease of interpretation. Parametric forms can be fully described by a few parameters, while the empirical CDF requires the whole sample. Furthermore, if the parametric form is well chosen, specific values of the parameters will be associated with likely calibration problems in the probability assessment process. The principal disadvantage of a parametric approach is that the form chosen may not represent the calibration function well in particular cases.

The beta distribution, defined on the interval [0, 1], is a natural candidate for representing the calibration function. Its probability density function (PDF), $c(u)$, is

$$(16) \qquad c(u) = u^{p-1}(1-u)^{q-1}/B(p, q),$$

where B is the beta function (with the associated CDF denoted $B(u; p, q)$). The beta distribution is well known, flexible, and contains the uniform distribution as a special case ($p = q = 1$). The two parameters of this distribution can be easily estimated by applying maximum likelihood methods to the sample values of U_t.

The beta distribution can assume any of the four basic patterns of calibration functions discussed above (in addition to $p = q = 1$): flat-steep-flat ($p, q > 1$), steep-flat-steep ($p, q < 1$), flat-steep ($p > 1$, $q < 1$) and steep-flat ($p < 1$, $q > 1$). The condition associated with no location bias, i.e., $C(0.5) = 0.5$, occurs when $p = q$. No simple comparable condition exists for bias in dispersion. However, if p and q are nearly equal, indicating little location bias, values of p and q greater than one indicate overassessment of dispersion, while values of p and q less than one indicate underassessment.

It is possible for the calibration of an assessment process to change over time or to be dependent on conditioning variables. For example, if option premiums incorporate a risk premium which increases with the volatility of the price of the underlying asset, then the divergence between the RNVM and an objective probability measure would also increase with volatility. Furthermore, option-based probability assessments implicitly depend on the assessments made by options traders, who can learn if their assessments are unreliable. This might result in option-based assessments becoming more calibrated as an option market matures. Unfortunately, the recent opening of agricultural option markets limits available data; therefore, a simple unconditional calibration function is estimated for each sample examined in this study.

Tests of Calibration

An examination of whether observed departures from calibration are statistically significant can be based on goodness-of-fit tests for uniformity on [0, 1]. Three approaches to testing for uniformity are used in this study, with the main focus on detecting potential problems in the assessment of location and dispersion.

The first test is based on the percentage of the u_t values lying within an interval of length 0.5 on the interval [0, 1]. Under the null hypothesis, the chance that a realization of U will lie in any such range is 50%. The interval [0, 0.5] provides information on bias in location (median), while the interval [0.25, 0.75] provides information on bias in the dispersion (interquartile range). This test is a variant of the sign test, which rejects the null hypothesis if the percentage falling into such an interval is either too large or too small relative to a binomial distribution in which the probability of a "success" is 0.5.

Nonparametric goodness-of-fit tests based on the empirical CDF comprise the second approach. Stephens discusses and evaluates a

number of such tests, including the familiar Komolgorov test. Each of the tests varies in relative power against alternative hypotheses. The Watson U^2 and the Cramer-von Mises tests appear to be relatively powerful against alternatives associated with nonuniform dispersion and location, respectively. Further power tests by Quesenberry and Miller support this finding and indicate that the Watson test is a good candidate for a single omnibus test of uniformity.

A third approach uses the maximum likelihood parameter estimates of the fitted beta calibration function to construct a likelihood ratio statistic for the hypothesis that $p = q = 1$, the parameter values for the uniform special case. Because the loglikelihood of the uniform distribution is always equal to zero, the likelihood ratio statistic is twice the maximum likelihood. This test statistic has an asymptotic chi-square distribution with two degrees of freedom. Monte Carlo simulation results performed by the authors suggest that the test statistic should be multiplied by a small sample correction factor of $(1 + 1/n)$, where n is the sample size. Further simulation results indicate that this test statistic compares favorably in power to the nonparametric tests examined by Stephens.

Testing the Calibration of Option-Based Probability Assessments in Agricultural Markets

Option trading for soybeans and cattle began in October 1984, while trading for corn and hogs began in February 1985. The options are written on futures contracts. For cattle and hogs, those futures contracts expire in February, April, June, August, October, and December. For soybeans, they expire in January, March, May, July, September, and November; for corn they expire in March, May, July, September, and December.[4] For all of these commodity options, trading ends on a Friday one to two business weeks prior to the beginning of the futures contract delivery month. The expiration date futures price is taken to be the close price on the last trading date of the options. Samples of size 15, 20, 20, and 18 (July 1985–May 1988, March 1985–May 1988, Feb. 1985–Apr. 1988, and June 1985–Apr. 1988) were used for corn, soybeans, cattle, and hogs, respectively. Futures prices and option premiums for corn and soybeans prior to 1986 are from Chicago Board of Trade tapes. All other data are from the *Wall Street Journal*.

Probability assessments for each commodity were generated on dates eight and four weeks prior to expiration. These assessments were used to construct two samples (per commodity) of realized CDF values, i.e., of U_i. The CDF values within each sample can be viewed as independent random variables because the periods between assessment and expiration dates do not overlap. Thus, each sample can be used to test for calibration. The two samples for each commodity are not independent because the period between assessment and expiration dates of the four-week assessment is always encompassed by that of the eight-week assessment. Thus, it is inappropriate to pool the samples. However, presenting the results for both samples does indicate possible changes in the calibration of option-based assessments as the forecast period changes.

CDF values associated with the expiration date futures price for each of the eight samples were used to construct the empirical and fitted beta calibration functions shown in figure 2.[5] The calibration functions estimated by the two methods have similar shapes, supporting the use of the beta distribution as a parametric form for representing calibration functions. The main exceptions are in the eight-week samples for corn and cattle, both of which have empirical, but not beta, calibration functions that exhibit flat areas in the center portion of the [0, 1] interval. One should suspect therefore that, in these cases, test results based on the beta distribution may be in conflict with those based on nonparametric methods.

The shapes of the calibration functions vary considerably across these markets. For corn and cattle the calibration functions are difficult to characterize and are not consistent between the eight- and four-week samples. The eight-week sample for corn has a steep-flat-steep pattern, while the four-week sample has a flat-steep-flat pattern. These patterns are roughly associated with problems in the under- and over-assessment of dispersion. The eight-week cattle sample has a steep-flat-steep pattern, while the four-week sample has a flat-steep pattern. For soybeans, however, both samples clearly exhibit a flat-steep-

[4] August soybean and July hog contracts are also traded. However, these contracts were not used so that two-month periods between expiration dates could be maintained, thereby eliminating the possibility of overlapping forecast periods. The expiration dates are spaced two or three months apart in the corn market.

[5] For ease of interpretation, the empirical calibration function is presented as a piecewise linear function that linearly interpolates the points $\{u_i, (i - 0.5)/n\}$, with u_i sorted and using (0, 0) and (1, 1) as endpoints.

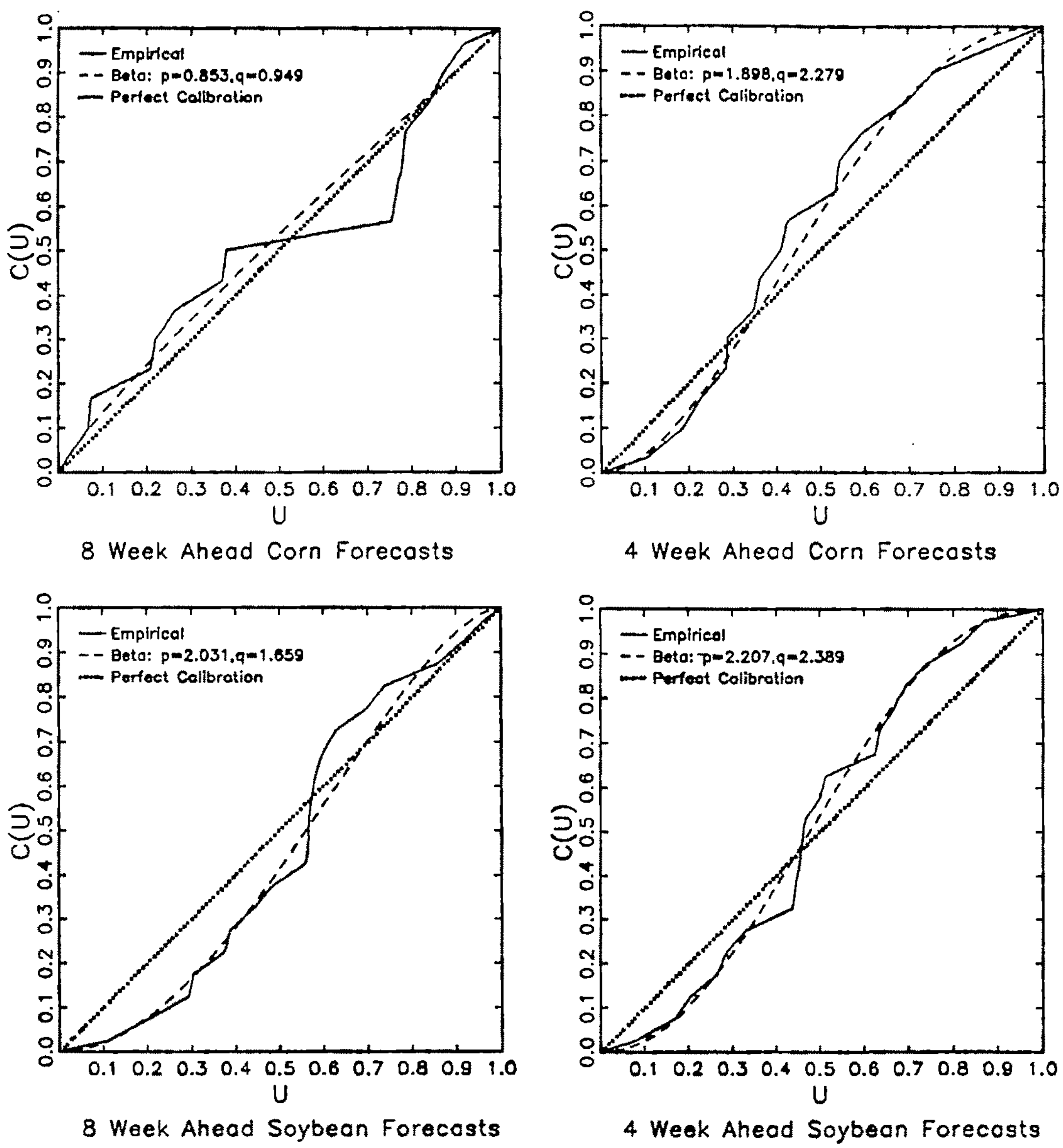

Figure 2. Empirical and beta calibration functions

flat pattern, while for hogs both exhibit a flat-steep pattern. These patterns suggest that probability forecasts in the soybean and hog markets exhibit overassessment of dispersion and underassessment of location, respectively.

Statistical results in table 2 largely confirm the graphical results. The sign test results show the percentage of observations in each sample falling into the [0, 0.5] and [0.25, 0.75] intervals, as well as the associated p-values for the two-sided test. Tests on the first of these intervals suggest problems in assessing location in the four-week hog sample, and, weakly, in the four-week cattle sample. The second of these intervals suggests problems in assessing dispersion in both soybean samples and both corn samples, although only weakly in the four-week corn case. For corn, however, the eight-week sample has too few observations in the [0.25, 0.75] interval, while the four-week sample has too many.

These results are generally consistent with those of the nonparametric Watson and Cramer-von Mises tests. No assessment problems are indicated for corn and cattle. On the other hand, the Watson test rejects the null hypothesis in both

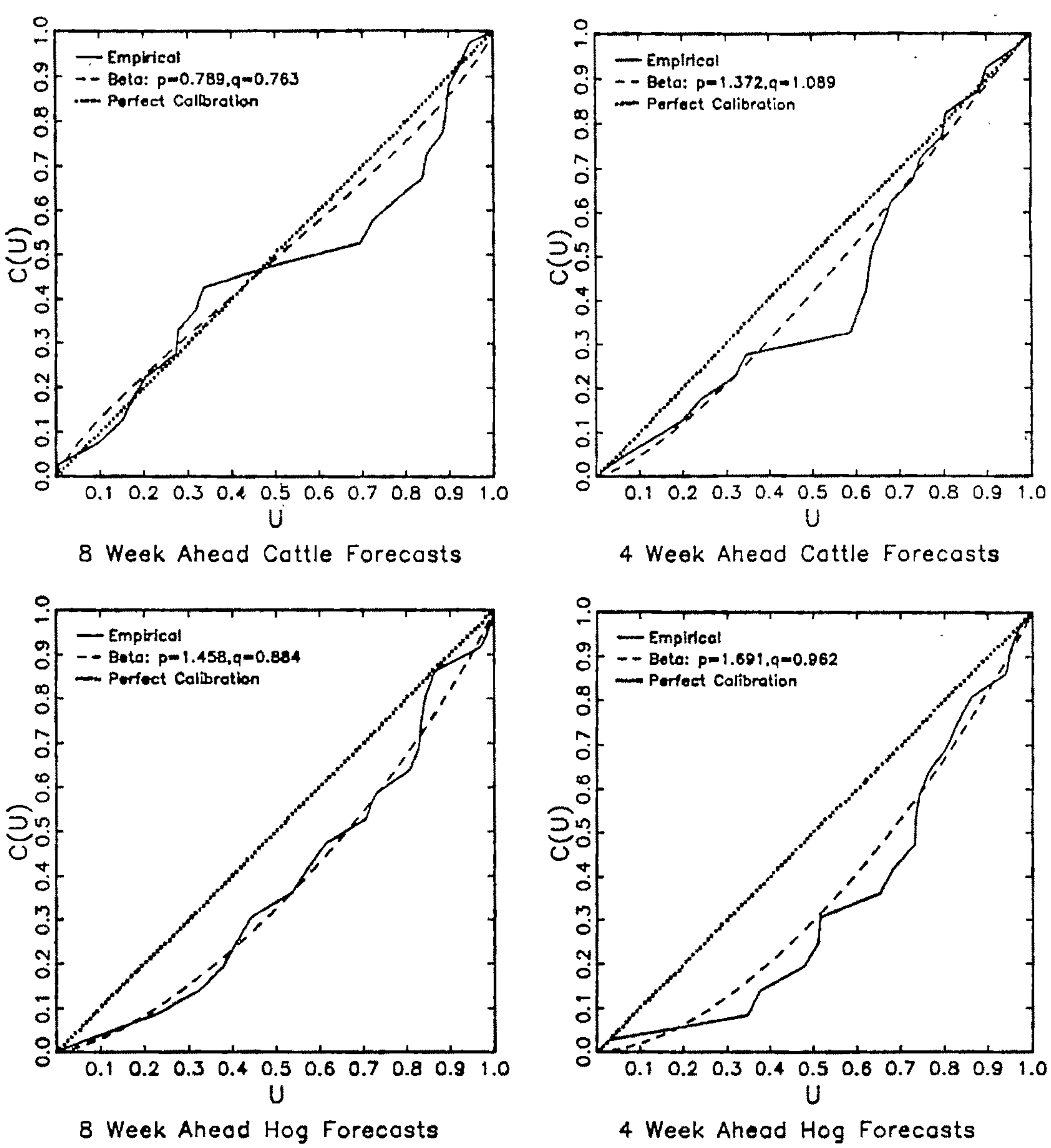

Figure 2. Continued

soybean samples. For hogs both tests reject the null hypothesis at the 0.05 significance level in the four-week case, while the null hypothesis is rejected at the 0.15 level by the Cramer-von Mises test in the eight-week sample.

The parametric (beta distribution) test results provide only weak evidence of noncalibration in the four-week sample in the corn market and none in the cattle market. Calibration problems are indicated in both soybean and hog markets, with the problems in both cases most evident in the four-week samples.

Taken together, these results suggest calibration problems in option-based probability forecasts for both the soybean and hog markets. For soybeans these problems involve overassessment of dispersion; for hogs they involve underassessment of location, although the evidence for this is not quite as strong.[6] The corn market results are somewhat ambiguous, but they do not

[6]An examination of hog futures prices in the period 1976–84 (prior to options trading) reveals no evidence that the probability of an up or down movement was other than 50% at either the 4- or 8-week horizon. The results for the 1985–88 period therefore reflect recent developments in this market or are attributable to sampling error.

Table 2. Calibration Test Results

Samples	Sign Tests (%) [0, 5]	Sign Tests (%) [.25, .75]	Cramer-von Mises W^2	Watson U^2	Beta LR
Corn					
8-Week	53.3 (.607)[a]	20.0 (.035)	0.97	.113	0.277 (.871)
4-Week	60.0 (.302)	66.7 (.118)	.148	.117	4.398 (.111)
Soybeans					
8-Week	40.0 (.503)	75.0 (.012)	.182	.157@	4.457 (.108)
4-Week	60.0 (.263)	75.0 (.012)	.147	.154@	6.868 (.032)
Live cattle					
8-Week	50.0 (.824)	35.0 (.263)	.144	.127	1.057 (.590)
4-Week	30.0 (.115)	55.0 (.503)	.237	.130	1.290 (.525)
Hogs					
8-Week	33.3 (.238)	50.0 (.815)	.320*	.065	3.585 (.167)
4-Week	22.2 (.031)	55.6 (.481)	.675#	.187#	4.664 (.097)

[a] p-values are shown in parentheses; asterisk indicates significant at the 0.15 level; @ indicates significant at the 0.10 level; # indicates significant at the 0.05 level.

suggest that option-based probability forecasts exhibit a consistent noncalibration pattern. Instead, a change from under- to overassessment of dispersion is indicated when the forecast horizon is changed from eight to four weeks. Without further study, this apparent calibration problem is perhaps best attributed to sampling fluctuation.

For those markets with calibration problems, the option-based assessments can be transformed using the estimated calibration function (either the nonparametric or the beta). To illustrate, consider the probability distribution associated with the July 1988 soybean futures at the expiration of the associated option (17 June 1988). On 22 April 1988, the log-normal option-based assessment was $G(Y_T) = \Phi((\ln(Y_T) - 6.508)/0.08174)$. However, given the relevant calibration function (8-week soybean) shown in figure 1, an improved assessment could be obtained by using $F(Y_T) = B(G(Y_T), 2.031, 1.659)$.

Table 3 contains a comparison of selected percentiles of these two distributions. The calibrated distribution has shifted the median up by nearly 8.5¢ and reduced the interquartile range by nearly 30% from 73.0¢ to 52.5¢. Because of unanticipated drought conditions, the realized expiration date price of 971.5 was in the extreme right-hand tail of both distributions.

Table 3. A Comparison of Selected Fractiles for a Noncalibrated and a Calibrated Probability Assessment

U	Noncalibrated ($G^{-1}(U)$)	Calibrated ($F^{-1}(U)$)
0.05	586.16	618.21
0.10	603.82	631.11
0.25	634.54	653.26
0.50	670.51	678.89
0.75	708.51	705.74
0.90	744.55	731.12
0.95	767.00	746.93

Concluding Comments

This paper focuses on methods for assessing and evaluating price probability distributions based on options market data. The recent development of agricultural option markets makes this a timely topic, but it also allows for only a preliminary evaluation of these methods. Nonetheless, the applications in the four commodity markets demonstrate the potential of the methods. Option premiums can be used to provide information on price probability distributions, yielding a complete assessment of the stochastic nature of prices that is easily obtainable at low cost and that can be regularly updated.

The results of this paper suggest that there are differences among markets in the reliability of option-based probability assessments. Little evidence was found of any systematic assessment problems in the corn and live cattle markets. However, the results suggest that option-based assessments of price distributions overstate the variability of soybean prices and underpredict the location of hog prices.

The results presented here are preliminary, pending maturity of the options markets under study. However, they present both a framework for the study of the reliability of probability assessments and demonstrate the ability of the statistical tests used to both support and reject the null hypothesis of calibration. Further research could usefully explore the causes of apparent noncalibration, particularly in the soybean market. It would also be useful to compare the reliability of option-based assessments with other assessment methods. Clearly, options markets provide a rich data base for further study.

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The Reaction of Live Hog Futures Prices to USDA *Hogs and Pigs Reports*

Phil L. Colling and Scott H. Irwin

Strong concerns about how efficiently live hog futures prices react to U.S. Department of Agriculture *Hogs and Pigs Reports* have been raised by livestock producer groups. Using market survey data, direct tests of the efficient markets hypothesis are performed for the live hog futures market. Two-limit tobit models account for institutional price limits. Results support the efficient market hypothesis in that live hog futures prices (*a*) do not react to anticipated changes in reported information, (*b*) do react significantly and in the expected direction to unanticipated changes in reported information, and (*c*) generally adjust to unanticipated information on the day following release of the reports.

Key words: efficient market hypothesis, expected information, survey data, two-limit tobit model, unanticipated information.

A market is efficient if prices discovered in that market fully reflect all available information (Fama). Therefore, in an efficient market, price changes should occur only as the result of new information. Old information is already incorporated into price and should therefore lead to no further price changes. In addition, price changes as the result of new information should occur rapidly, perhaps instantaneously.

Prices on various markets often react sharply after the release of new major information. For example, stock prices often change substantially after the release of reports on trade, inflation, unemployment, and capacity utilization. Commodity futures prices often change after the U.S. Department of Agriculture (USDA) releases various crop and livestock reports. However, prices sometimes do not change or change only slightly after the release of reports. In such cases, the market may have accurately anticipated the report information. In an efficient market, price changes should reflect differences between market expectations of new information and the actual information upon release.

A controversial example of the release of important new information is the quarterly USDA *Hogs and Pigs Report,* where estimates of the size of the total hog inventory, breeding and market hog inventories, and farrowing intentions are reported. Livestock producer groups have voiced strong concerns that live hog futures prices do not react efficiently to the information contained in the *Hogs and Pigs Reports*. The purpose of this paper is to test the hypothesis of market efficiency for the live hog futures market.

Previous studies of the effect of *Hogs and Pigs Reports* on live hog futures prices (USDA; Miller; Hoffman; Hudson, Koontz, and Purcell) do not use survey data of market expectations to distinguish between anticipated and unanticipated information. Hence, direct tests of market efficiency are not possible. In this study, survey data of market analysts' expectations of changes in breeding and market hog inventories are used to distinguish between anticipated and unanticipated information. The survey data are tested to determine their appropriateness with regard to unbiasedness, efficiency, and forecast performance. Then, maximum-likelihood estimation of two-limit tobit models and likelihood-ratio tests are used to determine if anticipated and unan-

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ticipated information has subsequent effects on prices after the report release. The possibility of predictable price patterns up to four days after the reports is also examined.

Throughout the paper, reference is made to three categories of information. These include expectations, report, and unanticipated information. Expectations information refers to the prereport expectations of reported information. This is sometimes referred to as "anticipated" information. Report information refers to the information contained in the USDA *Hogs and Pigs Reports*. Unanticipated information refers to the difference between expectations and report information.

Review of Previous Research

Previous studies of the effects of USDA reports on commodity futures prices provide only indirect evidence to support the efficient markets hypothesis. Like most studies of stock price behavior (i.e., Fama et al., Castanias), they observe the behavior of futures prices around the announcement date. Gorham studies the changes in soybean, wheat, and corn prices after the releases of monthly USDA crop production forecasts. He observes the changes in prices after the announcements, given the differences in the most recent forecasts and the forecasts of the previous month. Results indicate that changes in production harvest forecasts, and to a lesser degree wheat production forecasts, have a significant effect on subsequent price changes. Because changes in soybean production forecasts do not have a significant effect on price, he concludes that traders are better able to anticipate forecasts for soybean production as compared to corn or wheat production. Fackler, comparing the variance of price changes of corn and soybean futures after the release of reports to all other times, finds that variance is 2.5 times greater after the release of those reports for both contracts. This indicates that price adjustments occur in response to the reports supporting the notion of market efficiency.

Miller, USDA (1977), and Hoffman study the short-term behavior of live hog futures prices before and after the release of USDA *Hogs and Pigs Reports*. Miller examined price changes one day before and after the release of reports, whereas USDA (1977) and Hoffman used weekly averages of prices before and after the release of the reports. The results of the three studies suggest that futures prices generally react quickly to new information, but some exceptions are noted, especially for deferred contracts. Hudson, Koontz and Purcell study longer-term behavior of live hog futures prices by using prices twenty days before and after the release of *Hogs and Pigs Reports*. They concluded that live hog futures prices "adjust to new information in the *Hogs and Pigs Reports* rapidly and, in general, move in the appropriate direction" (p. 36). However, they also argue that the market is efficient but that it lacks sufficient information. Like most studies of stock market behavior, the above studies do not discriminate between anticipated and unanticipated components of new market information. It also appears that price limits are not accounted for, which would bias the results.

Barnhart's study is unique in that survey data of market participants' expectations of changes in fundamental variables are used to construct measures of anticipated and unanticipated changes in information. He estimates the effects of anticipated and unanticipated changes in the money supply, the Federal Reserve discount and surcharge rates, the consumer price index, the producer price index, the unemployment rate and the U.S. industrial production index on futures price changes for several commodity futures contracts. The sample runs from 1977 through 1984 and is broken into three subsamples to account for different monetary policy regimes over the period. For some contracts, it is found that prices do not adjust immediately to unanticipated information. This is possibly attributable to transactions costs, information costs, or institutional characteristics. It is unclear as to whether price limits are considered.

Theoretical Considerations

The following general model (Pearce and Roley) is used to investigate the response of live hog futures prices to anticipated and unanticipated information and to test basic hypotheses of efficient markets:

$$\Delta FP_t = a + x_t^u{*}b + x_t^e{*}c + \sum_{i=1}^{m} x_{t-i}^u{*}d + \mu_t, \tag{1}$$

where ΔFP_t is the percent change in closing futures prices from day $t - 1$ to day t; x_t^e is a ($1 \times k$) vector of expected informational components given information known on the close of trading on day $t - 1$; x_t^u is a ($1 \times k$) vector of

unanticipated informational components, derived as the difference between announced components, x_t^a, and expected components, x_t^e; x_{t-i}^u is a $(1 \times k)$ vector of unanticipated components occurring i days prior to day t; μ_t is a stochastic error term; a is a constant and b, c, d_i are $(k \times 1)$ vectors of parameters. If market expectations are rational, then

$$(2) \qquad x_t^e = E(x_t^a | \Omega_{t-1}),$$

where x_t^a is a $(1 \times k)$ vector of announced information, and Ω_{t-1} is the information set on the close of day $t - 1$ in order that $(x_t^a - x_t^e)$ is uncorrelated with Ω_{t-1}.

Under the efficient markets hypothesis, each element of c should not be significantly different from zero because all known information, Ω_{t-1}, should be reflected in the previous day's closing futures price, FP_{t-1}. Also, each element of d_i should not be significantly different from zero because nonzero elements would imply that futures prices adjust slowly to new information. Therefore, if the market is efficient, model (1) becomes

$$(3) \qquad \Delta FP_t = a + x_t^u{*}b + \mu_t,$$

and model (3) should not be rejected in favor of equation (1). If this holds, then equation (3) becomes the relevant model to determine the effect on futures price changes after unanticipated information is realized.

Given the nature of the major information released in the USDA *Hogs and Pigs Reports*, the independent variables for this study ideally would include anticipated and unanticipated changes in breeding and market hog inventories as well as farrowing intentions. However, survey data are unavailable for anticipated changes in farrowing intentions. Hence, the model for this study includes only anticipated and unanticipated changes in breeding and market hog inventories. However, correlation coefficients for actual changes in breeding hog inventories and farrowing intentions are quite high. The correlation coefficient for actual changes in breeding hog inventories and farrowing intentions during the quarter including the month of and the two months following the survey date is 0.94. The correlation coefficient for actual changes in breeding hog inventories and farrowing intentions during the quarter four to six months after the survey date is 0.88. This suggests that correlations between unanticipated changes in those categories might also be high. Therefore, much of the impact of unanticipated changes in farrowing intentions likely is captured by unanticipated changes in breeding hog inventories.

Based on the specified model, anticipated information concerning changes in breeding and market hog inventories should be fully reflected in live hog futures prices before the release of the *Hogs and Pigs Reports*. Therefore, after the reports are released, anticipated information should lead to no further price changes. Price changes should only reflect new information associated with the reports.

In general, the relationship between live hog futures prices and unanticipated changes in hog inventories should be negative. That is, if a report shows that hog inventories are higher than expected just before the release of the report, or that supply is higher than expected, then prices should drop after the release of the report, and vice versa. Prices should adjust rapidly after the release of reports.

More specifically, prices of nearby futures contracts should be more responsive to unanticipated changes in market hog inventories because this unanticipated supply will be ready for market in the near term. Contracts which expire at a time approximately equal to a hog production cycle (approximately eight to ten months) should be more responsive to unanticipated changes in breeding hog inventories. This would reflect unanticipated changes in the potential nearby pig crop which would be ready for market at that time. It is somewhat unclear how distant contracts, beyond a production cycle, would be affected by surprises in breeding and market hog figures. However, the negative relationship between unanticipated figures and futures prices for those contracts should exist.

Data

Closing live hog futures prices are collected on the days the *Hogs and Pigs Reports* are released, along with those one through four trading days after and two days prior to the release of the reports. Various time horizons of live hog futures contracts are defined corresponding to the approximate number of months from the time the *Hogs and Pigs Reports* are released until the contracts expire. Because futures contracts do not exist for every month of the year, it is impossible to obtain a perfectly balanced design. Five time horizons are defined, with the nearby time-horizon contracts expiring approximately two to three months after the report releases and with the distant time-horizon contracts expiring

Table 1. Futures Contracts Used for Each Time Horizon

	Quarterly Report			
Time Horizon	March	June	Sept.	Dec.
1	June (3)	Aug. (2)	Dec. (3)	Feb.+[a] (2)
2	July (4)	Oct. (4)	Feb.+ (5)	Apr.+ (4)
3	Oct. (7)	Feb.+ (8)	Apr.+ (7)	July+ (7)
4	Feb.+ (11)	Apr.+ (10)	July+ (10)	Oct.+ (10)
5	Apr.+ (13)	June+ (12)	Oct.+ (13)	Dec.+ (12)

[a] A (+) indicates that the corresponding contract month is used for the year following the *Hogs and Pigs Reports*. Numbers in parentheses are the approximate number of months after the report release to the expiration of the futures contract.

in about twelve to thirteen months. Table 1 lists the futures contracts used for each time horizon along with the corresponding number of months after the release of the reports until expiration of the contracts. The various time horizons allow for comparison of the specific effects of anticipated and unanticipated changes in breeding and market hog inventories across a wide spectrum of futures contracts.

An average of market analysts' expectations is used as the proxy for market expectations of reported changes in breeding and market hog inventories from year-ago levels. Analyst expectations are collected in a survey by Futures World News. Specifically, fifteen analysts on average are canvassed regarding their expectations of changes in total, breeding, and market hog inventories. Survey results are released after the close of trading two days before the USDA *Hogs and Pigs Report* is announced. Subsequent actual changes in ten-state breeding and market hog inventories from year-ago levels are published in quarterly USDA *Hogs and Pigs Reports*.[1] The USDA report is released after the close of trading on the announcement day. The sample period runs from the September 1981 through the June 1988 reports, providing twenty-eight observations.

To examine the suitability of the market survey data with respect to unbiasedness, efficiency, and forecast performance, four tests are performed, following the methodology set forth by Pearce and Roley. If these tests are passed, then the data are deemed appropriate for testing the efficient markets hypothesis. The first test is designed to determine if the survey data are unbiased. No systematic bias should be revealed if the survey data are rational. The following models are estimated using ordinary least squares:

(4) $$BRD_t^a = \beta_0 + \beta_1 BRD_t^e + \mu_t \text{ and}$$

(5) $$MKT_t^a = \beta_0 + \beta_1 MKT_t^e + \mu_t$$

where *BRD* denotes changes in breeding hog inventories from the year-ago level, *MKT* denotes changes in market hog inventories from the year-ago level, a superscript *e* denotes expected information, a superscript *a* denotes actual information, and a subscript *t* denotes the report release date. A paired *F*-test is performed to test the null hypothesis H_0: $\beta_0 = 0$, $\beta_1 = 1$ for both breeding and market hogs. The marginal significance levels reported in table 2 indicate that unbiasedness can not be rejected.

Because important new information could affect live hog futures prices in the two days between the release of the survey of market analysts and the release of the *Hogs and Pigs Reports,* a second test of unbiasedness is conducted. Following Pearce and Roley, new information is assumed to be reflected by the percentage change in closing futures prices from the release date of the market analysts' survey to the release date of the USDA *Hogs and Pigs Reports*. Hence, the following models are estimated using ordinary least squares:

(6) $$BRD_t^a = \beta_0 + \beta_1 BRD_t^e + \beta_2 \Delta FP_t^i + \mu_t \text{ and}$$

[1] Prior to the June 1982 USDA *Hogs and Pigs Report*, quarterly data were based on 14 states. Therefore, in our sample, the first three observations are based on 14-state data. To determine if this biased the results, all estimations were reestimated with the first three observations deleted. The results were virtually identical, indicating that no substantial bias exists. Results presented are those of the full sample period (28 observations).

Table 2. Tests of the Unbiasedness of the Survey Data

Report Figure of	Coefficient Estimates β_0	β_1	Summary Statistics[a] Adj R^2	S.E.	D-W	H_0: $\beta_0 = 0$, $\beta_1 = 1$ $F(2, 26)$	M.S.[b]
Breeding hogs	−.908 (.617)	.997 (.089)	.82	3.15	1.95	1.152	.332
Market hogs	.332 (.392)	.950 (.054)	.92	2.00	2.09	1.075	.356

Note: Standard errors of the estimated coefficients are in parentheses.
[a] Adj R^2 is adjusted R^2; S.E. is standard error; D-W is Durbin-Watson d.
[b] M.S. is marginal significance level.

$$(7) \qquad MKT_t^a = \beta_0 + \beta_1 MKT_t^e + \beta_2 \Delta FP_t^i + \mu_t,$$

where ΔFP_t^i is the difference between the natural logarithms of the closing futures prices on the release dates of the market analysts' survey and the USDA report for time horizon i ($i = 1, \ldots, 5$). This price change is simply a proxy for new information. All other variables are defined for equations (4) and (5). If either of the β_2 coefficient estimates from (6) and (7) are significantly different from zero, this would indicate that new information consistently enters the market in a nonrandom fashion between the release of the survey and the report. In such a case, the survey data of market expectations could be consistently biased. The data then would need to be adjusted to reflect that bias. In none of the ten estimated equations is the β_2 coefficient significant or the β_0 and β_1 coefficients substantially changed from estimates presented in table 2.[2] Thus, on average, no new important information is released between the survey and the USDA report. As a result, there is no need to adjust the survey expectations to reflect a revised market expectation.

In the third test the efficiency of the survey data is tested by estimating the following models:

$$(8) \qquad BRD_t^u = \beta_0 + \beta_1 BRD_{t-1}^a + \mu_t, \text{ and}$$

$$(9) \qquad MKT_t^u = \beta_0 + \beta_1 MKT_{t-1}^a + \mu_t,$$

where a superscript u denotes unanticipated information, computed as the difference between changes reported in the *Hogs and Pigs Reports* and analysts' survey data. Using the final prediction error (FPE) criteria of Akaike, one lag is chosen for both models in which a total of four lags are allowed to enter. Pearce and Roley, citing Modigliani and Shiller, note that "the basic notion behind this concept is that if announced data are generated by an autoregressive process, the market's expectation should be generated by the same process" (p. 57). Lag coefficients should not be significantly different from zero. As table 3 indicates, the null hypothesis is not rejected.

The fourth test determines if forecasting autoregressive models can outperform the survey data. The following autoregressive models are estimated:

$$(10) \qquad BRD_t^a = \beta_0 + \beta_1 (BRD_{t-1}^a) + \beta_2 (BRD_{t-2}^a) + \mu_t, \text{ and}$$

$$(11) \qquad MKT_t^a = \beta_0 \text{ and } \beta_1 (MKT_{t-1}^a) + \beta_2 (MKT_{t-2}^a) + \mu_t.$$

Again, the FPE criteria is used to select the number of lags where up to four lags are allowed to enter. From table 4, the forecast root mean square error is lower for the survey data than for the autoregressive models for both breeding and market hogs, indicating that the survey data is a better forecaster than the models. The results are especially significant when it is noted that the model forecast errors are generated in-sample and the survey forecast errors are generated *ex ante* out-of-sample. As the forecasting accuracy of univariate time-series models is well known, this raises the interesting question of whether model-based forecasts of hog inventory categories (Blanton et al.) are economically valuable.

Based on the previous four tests, it is concluded that the survey data have desirable properties and are appropriate for direct tests of the efficient markets hypothesis. But before moving on to such tests, an important econometric problem must be addressed.

[2] These results are available from the authors upon request.

Table 3. Tests of the Efficiency of the Survey Data

Report Surprise in:	Coefficient Estimates		Summary Statistics[a]			Test H_0: $\beta_1 = 0$	
	β_0	β_1	Adj R^2	S.E.	D-W	$F(1, 27)$	M.S.[b]
Breeding hogs	−.753	.025	−.04	2.51	1.59	.118	.735
	(.534)	(.074)					
Market hogs	.381	−.052	−.01	2.02	2.07	.744	.398
	(.417)	(.060)					

Note: Standard errors of the estimated coefficients are in parentheses.
[a] Adj R^2 is adjusted R^2; S.E. is standard error; D-W is Durbin-Watson d.
[b] M.S. is marginal significance level.

Table 4. Tests of the Forecast Performance of the Survey Data

Report Figure of	Coefficient Estimates			Summary Statistics[a]			Forecast *RMSE*[b]	
	β_0	β_1	β_2	Adj R^2	S.E.	D-W	Auto[c]	Survey[d]
Breeding hogs	−.498	1.231	−.616	.72	3.69	1.57	3.23	3.17
	(.807)	(.169)	(.163)					
Market hogs	−.033	1.322	−.718	.81	2.93	1.65	2.56	2.00
	(.617)	(.141)	(.140)					

Note: Standard errors of the estimated coefficients are in parentheses.
[a] Adj R^2 is adjusted R^2; S.E. is standard error; D-W is Durbin-Watson d.
[b] *RMSE* is root mean square error.
[c] Autoregressive model
[d] Survey data

Econometric Model

A problem encountered in this research deals with institutional price limits of the Chicago Mercantile Exchange. Live hog futures prices are allowed to move by no more than $1.50 per hundredweight during a trading day from the previous day's closing price. If the price hits the limit, trades may still take place at that price. However, if the closing price is at the limit, this indicates an imbalance in supply and demand, and hence the closing price is not an equilibrium free market price. As a result, daily closing prices may be inappropriate for testing market efficiency and predicting price changes after report releases given unanticipated information. For example, if ordinary least square is applied to equation (3), the estimated coefficients of b would be biased toward zero because the dependent variable can take on only limited values or values between the limits. In this study, closing prices on days after the reports are limit moves for at least one-half of the twenty-eight observations for all five time horizons. Therefore, alternative measurement techniques must be examined in order to examine and test models (1) and (3).

To deal with this problem, maximum-likelihood estimation of the two-limit tobit model as presented by Rosett and Nelson is used to estimate parameters and test hypotheses. This allows for estimates of true price changes in light of price limits and the limited-dependent variable problem. Maddala notes that when the dependent variable is truncated on two sides but is allowed to vary freely within the two limits, the classical linear model becomes

$$y_i^* = \beta' x_i + \mu_i, \tag{12}$$

where y_i^* is the latent or sometimes unobserved variable. Denoting y_i as the observed variable, we have

$$\begin{aligned} y_i &= L_{1i} \text{ if } y_i^* \leq L_{1i}, \\ &= y_i^* \text{ if } L_{1i} < y_i^* < L_{2i}, \\ &= L_{2i} \text{ if } y_i^* \geq L_{2i}, \end{aligned} \tag{13}$$

where L_{1i} and L_{2i} are lower and upper limits, respectively, of the dependent variable for observation i. This model's likelihood function is given by

(14) $$L(\beta,\sigma|y_i, x_i, L_{1i}, L_{2i}) = \underset{y_i=L_{1i}}{\pi} \Phi\left[\frac{L_{1i}-\beta' x_i}{\sigma}\right] \underset{y_i=y_i^*}{\pi} \frac{1}{\sigma}\phi\left[\frac{y_i-\beta' x_i}{\sigma}\right] \cdot \underset{y_i=L_{2i}}{\pi}\left[1-\Phi\left[\frac{L_{2i}-\beta' x_i}{\sigma}\right]\right],$$

where ϕ and Φ are the density function and distribution function of the standard normal, respectively. This likelihood function accounts for all three possibilities given in (13). A modification of the Davidson, Fletcher, and Powell algorithm is used to optimize the likelihood function, as suggested by Gruvaeus and Joreskog. The covariance matrix is computed from analytic first derivatives of the likelihood function.

The potential for heteroscedasticity in futures price changes is well known (Hall, Brorsen, and Irwin). Hence, tests for heteroscedasticity are performed for all estimations. ML estimates of the following model, as specified by Rutemiller and Bowers and outlined in Maddala are obtained:

(15) $$\sigma_i^2 = (\tau + \delta Z_i)^2,$$

where σ^2 denotes a vector of squared error terms from the tobit models, τ denotes a constant, δ denotes a vector of parameters, and Z includes all independent variables. Likelihood-ratio tests of the restriction $\delta = 0$ are performed.

Results

To test the hypothesis that anticipated information of USDA *Hogs and Pigs Reports* has no effect on price changes after they are released, the following model is estimated for each time horizon:

(16) $$\text{Ln}(FP_t^1) - \text{Ln}(FP_t^0) = \beta_0 + \beta_1 (BRD_t^u) + \beta_2 (MKT_t^u) + \beta_3 (BRD_t^e) + \beta_4 (MKT_t^e) + \mu_t,$$

where FP denotes closing live hog futures price, a superscript 0 denotes the day of the report release, a superscript 1 denotes one trading day after the report release, and all other terms are as defined earlier. Unanticipated components are computed as the difference between actual and expected percent changes in inventories from the year-ago level. Price changes are computed as differences in natural logs so that they will represent fractional changes. The lower and upper limits for this tobit model are given by

(17) $$LL_t = \text{Ln}(FP_t^0 - LPC) - \text{Ln}(FP_t^0), \text{ and}$$

(18) $$UL_t = \text{Ln}(FP_t^0 + LPC) - \text{Ln}(FP_t^0),$$

where LL and UL denote lower limit and upper limit, respectively, and LPC denotes limit price change. For model (16), this is \$1.50 because we are dealing with one-day price changes. To test the efficient markets hypothesis, a likelihood-ratio test of the linear restriction, $H_0: \beta_3 = \beta_4 = 0$, is performed and t-statistics and standard errors of the estimated coefficients are observed.

Coefficient estimates of equation (16) are shown in table 5. No evidence of heteroscedasticity is found for any of the estimated equations. Likelihood-ratio tests and t-tests indicate that estimates of β_3 and β_4 coefficients of the

Table 5. Tests of the Significance of Anticipated Information On Live-Hog Futures Price Changes One Day After Report Releases

Time Horizon	Coefficient Estimates β_0	β_1	β_2	β_3	β_4	Likelihood Ratio Test; $H_0: \beta_3 = \beta_4 = 0$ Chi-SQ(2)
1	1.322	−.357	−1.284*[b]	.256	−.265	1.267
	(.884)[a]	(.373)	(.657)	(.228)	(.240)	
2	.953	−1.059*	−1.153	.210	−.211	.620
	(1.352)	(.602)	(.802)	(.267)	(.296)	
3	.735	−1.501**	−.630	.114	−.101	.218
	(1.264)	(.578)	(.747)	(.261)	(.296)	
4	.506	−1.407**	−.328	−.039	.048	.053
	(.755)	(.427)	(.504)	(.189)	(.206)	
5	1.255*	−.791*	−.582	.033	−.016	.078
	(.750)	(.362)	(.436)	(.176)	(.187)	

[a] Standard errors of the estimated coefficients appear in parentheses.

[b] One and two asterisks represent significance at the 5% and 1% levels, respectively. One sided t-tests are performed for coefficient estimates β_1 and β_2.

Table 6. Response of Live-Hog Futures Prices to Unanticipated Information One, Two, Three, and Four Days After Report Releases

	Coefficient Estimates for One-Day and Cumulative Two-, Three-, and Four-Day Models											
	One-Day Price Changes			Cumulative Two-Day Price Changes			Cumulative Three-Day Price Changes			Cumulative Four-Day Price Changes		
Time Horizon	β_0	β_1	β_2	β_0	β_1	β_2	β_0	β_1	β_2	β_0	β_1	β_2
1	.983	−.562*[b]	−.903*	1.216	−.564*	−.968**	1.216	−.532*	−.884*	.917	−.562	−.843
	(.776)[a]	(.320)	(.475)	(.706)	(.281)	(.391)	(.781)	(.307)	(.429)	(.926)	(.421)	(.513)
2	.631	−1.241*	−.819	1.457	−.817**	−1.114*	.979	−.768**	−.998*	.954	−.750*	−1.170*
	(1.335)	(.669)	(.774)	(.917)	(.340)	(.621)	(.762)	(.282)	(.466)	(1.033)	(.446)	(.599)
3	.575	−1.577**	−.473	1.049	−.996**	−.592	.915	−1.068**	−.563	.466	−1.023**	−.648*
	(1.133)	(.572)	(.674)	(.551)	(.296)	(.373)	(.586)	(.265)	(.359)	(.654)	(.298)	(.349)
4	.623	−1.489**	−.436	.955*	−.948**	−.501	1.382**	−.801**	−.713**	1.139*	−.859**	−.761**
	(.818)	(.427)	(.434)	(.460)	(.250)	(.333)	(.456)	(.226)	(.299)	(.492)	(.205)	(.274)
5	1.211	−.796**	−.560	.617**	−.662**	−.407	1.741**	−.639**	−.529*	1.513**	−.626*	−.608*
	(.650)	(.319)	(.342)	(.409)	(.191)	(.286)	(.486)	(.192)	(.306)	(.525)	(.295)	(.309)

[a] Standard errors of the estimated coefficients appear in parentheses.
[b] One and two asterisks represent significance at the 5% and 1% levels, respectively. One sided t-tests are performed for coefficient estimates β_1 and β_2.

expected components are not significantly different from zero. Therefore, anticipated information has no significant effect on live hog futures price changes after the release of the USDA *Hogs and Pigs Reports*. This result indicates that anticipated information is incorporated into price before the release of the reports, supporting the efficient market hypothesis. At this point, the first test of market efficiency has been passed, and c in (1) becomes zero, causing that term to be deleted from the model.

To estimate the impact of unanticipated information on one-day futures price changes, β_3 and β_4 are dropped from (16) and the following model is estimated:

$$(19)\quad \mathrm{Ln}(FP_t^1) - \mathrm{Ln}(FP_t^0) = \beta_0 + \beta_1(BRD_t^u) + \beta_2(MKT_t^u) + \mu_t$$

for all time-horizons where LPC from (17) and (18) is also \$1.50. Standard errors and t-statistics of the estimated coefficients are examined to determine their significance. A likelihood-ratio test of the linear restriction, $H_0: \beta_1 = \beta_2 = 0$, is performed to determine the joint significance of unanticipated information with regard to breeding and market hog inventory changes.

Coefficient estimates of equation (19) are presented in the first three columns of table 6. Again, evidence of a serious heteroscedasticity problem is not found. As expected, all signs of the estimated coefficients β_1 and β_2 are negative. Of the t-statistics for unanticipated market herd changes, only that of time-horizon 1 is significant at the 5% level. This supports the hypothesis that those changes have the greatest impact on nearby futures contracts. The t-statistics of unanticipated breeding herd changes are significant at the 5% level for time horizons 1 and 2 and at the 1% level for time horizons 3 through 5. Of the coefficient estimates for unanticipated breeding herd changes, that of time horizon 1 is least in absolute magnitude (0.562). The magnitude increases substantially at time horizon 2 (1.241). The absolute magnitudes of the unanticipated breeding herd coefficients are greatest for the models reflecting a time to expiration of the contracts approximately equal to a hog production cycle (1.577 and 1.489 for time horizons 3 and 4, respectively). Beyond a hog production cycle (time horizon 5), the absolute value of the coefficient estimate drops to 0.796.

The likelihood-ratio tests, shown in the first column of table 7, indicate that β_1 and β_2 for equation (19) are jointly significantly different from zero at the 1% level for all time horizons.

Table 7. Likelihood Ratio Tests of the Response of Live Hog Futures Prices to Unanticipated Information

Time Horizon	$H_0:\beta_1, \beta_2$ (Day 1) = 0 Chi-Square(2)	$H_0:\beta_1, \beta_2$(Day 2) = β_1, β_2(Day 1) Chi-Square(2)	$H_0:\beta_1, \beta_2$(Day 3) = β_1, β_2(Day 2) Chi-Square(2)	$H_0:\beta_1, \beta_2$(Day 4) = β_1, β_2(Day 3) Chi-Square(2)
1	13.783**[a]	2.334	4.979	1.984
2	11.414**	.323	2.841	.475
3	14.161**	5.261	4.924	4.263
4	15.889**	7.364*	6.623*	1.213
5	11.961**	.335	3.912	.480

Note: For the day-one models, likelihood ratio tests are performed to determine if β_1 and β_2 are jointly different from zero at significant levels. For the cumulative two-, three-, and four-day models, likelihood ratio tests are performed to determine if β_1 and β_2 are jointly different from estimated parameter values from one-day and cumulative two- and three-day models, respectively.

[a] One and two asterisks represents significance at the 5% and 1% levels, respectively.

This result indicates that unanticipated information significantly influences futures prices along the entire spectrum of time. In sum, the results from one-day price change models support the hypothesis that live hog futures prices react quickly and efficiently to new information.

To further test the efficient markets hypothesis, it is necessary to determine if predictable price patterns exist for several days beyond one day after the report releases, given the unanticipated information. Ideally, it would be desirable to test for one-day price changes beyond the first day after release of reports. This could be accomplished by changing the left-hand side of (19) to $\text{Ln}(FP_t^2) - \text{Ln}(FP_t^1)$, and $\text{Ln}(FP_t^3) - \text{Ln}(FP_t^2)$, and so forth. However, as mentioned earlier, about one-half of all closing prices one day after report releases are limit moves, as are several closing prices two days following reports. Therefore, the procedure mentioned above would lead to biased results and is not performed. As an alternative, the following models for all time horizons are estimated:

$$(20)\quad \text{Ln}(FP_t^2) - \text{Ln}(FP_t^0) = \beta_0 + \beta_1(BRD_t^u) + \beta_2(MKT_t^u) + \mu_t,$$

$$(21)\quad \text{Ln}(FP_t^3) - \text{Ln}(FP_t^0) = \beta_0 + \beta_1(BRD_t^u) + \beta_2(MKT_t^u) + \mu_t, \text{ and}$$

$$(22)\quad \text{Ln}(FP_t^4) - \text{Ln}(FP_t^0) = \beta_0 + \beta_1(BRD_t^u) + \beta_2(MKT_t^u) + \mu_t,$$

where superscripts 2, 3, and 4 represent trading days two, three, and four after the report releases. *LPC* from (17) and (18) are $3.00, $4.50, and $6.00 for (20), (21), and (22), respectively. This alternative is followed because the dependent variables in (20) through (22) represent cumulative price changes. For example, the dependent variable in (20) represents the change in price from the close of trade on the day of the report release to the closing price two trading days later. Because prices are permitted to move by $1.50 per day, the effective cumulative two-day price limit is $3.00 in this case. The effective cumulative three-day and four-day price limits are therefore $4.50 and $6.00, respectively. The independent variables in (19) through (22) are identical.

Parameter estimates of (20) through (22) appear in table 6 under the columns for cumulative two-day, three-day, and four-day price changes. A heteroscedastic error structure is not evident for any of the estimated equations. Most of the coefficient estimates for unanticipated changes in inventories are significant for the cumulative two-, three-, and four-day price change models, as is the case for one-day price changes. However, this does not imply that prices continue to adjust after day one. A significant cumulative price change may be the result of a large and significant price change on a single day and small and insignificant price changes on the other days in the summation. To determine if prices continue to adjust after the first day following the report, coefficient estimates between days must be compared. A significant change in β_1 and/or β_2 between days for any given time horizon may indicate that information is reinterpreted in a systematic fashion.

As a formal test of the hypothesis that price patterns cannot be predicted on days beyond the first day following release of the *Hogs and Pigs Reports*, likelihood-ratio tests are performed where β_1 and β_2 in (20), (21), and (22) are restricted to their estimated values in (19), (20), and (21), respectively. The test results, pre-

sented in the last three columns of table 7, offer further evidence in support of the efficient markets hypothesis. Test statistics were insignificant beyond day one for four of the five time horizons. Predictable price patterns are indicated only for time horizon 4 contracts. As shown by the test statistics, prices at this time horizon continue to adjust through the third day following report releases.

The specific pattern of price movements for time horizon 4 contracts is suggested by the changing magnitude of the estimated coefficients for this horizon (row four, table 6). Because β_1 equals -1.489 for day one, -0.948 for day two, and -0.801 for day three, an overreaction price pattern is suggested with respect to unanticipated changes in breeding inventories. Because β_2 is equal to -0.436 for day one and increases to -0.713 for day three, an underreaction price pattern is indicated for unanticipated changes in market inventories. The relatively large change in the magnitude of coefficients for unanticipated breeding inventory changes suggests that overreaction is the dominant price pattern for time horizon 4 contracts. Finally, the results do not necessarily imply that a profitable trading strategy could be developed to exploit the apparent price patterns. This is because of the existence of price limits and the high execution costs of trading in deferred futures contracts (Thompson and Waller).

Concluding Comments

Live hog futures prices often react sharply after the release of USDA *Hogs and Pigs Reports*. Strong concerns about how efficiently live hog futures prices react to those reports have been raised by livestock producer groups. Under the efficient markets hypothesis, live hog futures price changes after the release of *Hogs and Pigs Reports* should reflect only unanticipated changes in hog inventories, and no predictable price patterns should be found.

Using market survey data as a proxy for expected changes in breeding and market hog inventories contained in quarterly USDA *Hogs and Pigs Reports*, unanticipated changes in those figures are constructed. Therefore, expected and unanticipated changes are clearly differentiated allowing for a direct test of the efficient markets hypothesis in the live hog futures market. After showing that the survey data have desirable properties of unbiasedness, efficiency, and superior forecast performance, a direct test of the efficient markets hypothesis is performed. Maximum likelihood estimation of two-limit tobit models is used to account for institutional price limits.

The results offer strong support for the efficient markets hypothesis. First, it is found that expected changes in hogs and pigs inventories are incorporated into live hog futures prices before the release of the reports, and, hence, the expected changes have no effect on price changes after the release of the reports. Second, live hog futures prices across the spectrum of time react significantly and in the expected direction to unanticipated information. It is found that nearby contract prices are most responsive to unanticipated changes in market hog inventories, while the contracts expiring at a time horizon approximating one hog production cycle are most responsive to unanticipated breeding hog inventory changes. Third, predictable price patterns beyond the first day following the release of *Hogs and Pigs Reports* are not evident for four of the five contract time horizons examined in the study. Prices for one of the deferred contract time horizons adjust through the third day following report releases. However, this does not imply that a profitable trading strategy can be constructed to exploit the apparent price pattern. The existence of price limits and high execution costs of trading in deferred live hog futures contracts are likely to preclude such a possibility.

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A Simulation Model of the U.S. Export Enhancement Program for Wheat

Ann Hillberg Seitzinger and Philip L. Paarlberg

Nash bargaining game models representing negotiations of Export Enhancement Program (EEP) sales are combined with a quarterly spatial price equilibrium model representing non-EEP world wheat trade to simulate the EEP's impact in late 1985 and early 1986. The benefits of the EEP in terms of increased U.S. export revenues adjusted for subsidy costs are estimated to be less than one percent of total U.S. revenues. For the first quarter of 1986, model simulations also show a lowering of the CCC loan rate to have a much greater potential for increasing U.S. wheat exports than the EEP as operated.

Key words: export enhancement program bonus value, Nash bargaining game.

The United States introduced the Export Enhancement Program (EEP) in May 1985 to help alleviate the agricultural sector's financial stress. Payment-in-kind of export subsidies from government-owned stocks were authorized for select, or "targeted," import markets. Increased U.S. export sales were to be achieved through the displacement of subsidized European Community (EC) exports.

As a form of price discrimination among import markets, targeted export subsidies potentially can benefit the subsidizing exporter. Small export subsidies targeted toward markets with relatively more price-responsive behavior can raise export revenues or social welfare as conventionally defined. These gains are achieved without recourse to domestic policies, such as production controls (Abbott, Paarlberg, and Sharples). Further, Houck has demonstrated that in-kind subsidies may offer the exporter a positive terms-of-trade effect not available under a cash subsidy.

The EEP offers several potential benefits to the United States. Commodity groups in the United States hail the program as a success, while competing exporters complain that it has disrupted world markets. This article evaluates the impacts of the Export Enhancement Program on world wheat markets. It focuses on the program's effect on the export earnings of the United States and of its competitors. An additional scenario compares the use of the EEP to expand U.S. exports with the effect of a reduction in the Commodity Credit Corporation (CCC) loan rate. To determine these impacts, Nash bargaining models are solved iteratively with a spatial price equilibrium model of world wheat trade.

Program Operation

Knowledge of how the EEP works is critical to understanding the importance of the bargaining models to the EEP model's solution. Under the EEP, the Commodity Credit Corporation is to target countries for subsidized sales of U.S. commodities based on the following criteria:

1. additionality—sales must increase U.S. agricultural exports above what would have occurred in the absence of a program;
2. targeting—sales will be targeted on specific market opportunities, especially those that challenge competitors which subsidize their exports;
3. cost effectiveness—sales should result in a net plus to the overall economy;
4. budget neutrality—sales should not increase budget outlays beyond what would have occurred in the

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absence of the program. (*Federal Register*, pp. 23750–51.)

The U.S. Department of Agriculture (USDA) may either determine its own subsidy level as done in past U.S. export subsidy programs or allow the bonus level to result from a bidding process. In the latter and more prevalent case, CCC first issues an EEP invitation to the targeted importing country specifying the maximum quantity of commodity to be exported under the invitation. Qualified firms may then negotiate conditional sales with the targeted country (FAS).

In turn, the conditional sales contracts are submitted to the Commodity Credit Corporation along with the firms' bids for EEP bonuses. A bid takes the form of a dollars and cents per unit bonus, as estimated by the firm, required to make U.S. wheat competitive with wheat from other exporting countries. The CCC accepts or rejects the EEP bonus bids on a daily basis, taking into consideration the following factors: prevailing market prices of various exporters' wheat in the targeted country, freight rates, and purchasing practices peculiar to the targeted country. A firm holding a successful bid exports the wheat to the targeted country and requests that a bonus certificate be issued by CCC. The certificate value is calculated as the per unit bonus value multiplied by the quantity of wheat shipped to the targeted country. Commodities valued at the market prices are then selected from government stocks by the individual redeeming the bonus certificate. Firms with rejected bids may revise and resubmit their bids.

As an example consider the following EEP sale to Algeria. On 4 June 1985, USDA announced the availability of EEP bonuses for up to one million metric tons of non-durum wheat destined for Algeria. Negotiations between Algeria, exporting firms, and the CCC resulted in EEP sales of 135,000 metric tons of soft red winter wheat and 170,000 metric tons of hard red winter wheat on 15 October 1985. Five exporters had submitted a total of thirty-six bids to the CCC on the previous day, of which fifteen bids from four exporters were accepted. An average bonus of $40.56 per ton was paid on the soft red winter wheat, with Algeria paying a sales price of $103.00 per ton. For the hard red winter wheat selling at $111.00 per ton, an average bonus of $42.93 per ton was paid. Thus, bonus certificates totaling approximately $12.8 million were issued in relation to these EEP sales. When redeemed for CCC wheat stocks with a prevailing U.S. market price of $115.74 per ton, 110,363 metric tons of wheat would be released from storage.[1]

The Model

Because the export subsidy under the EEP is determined by a bidding process which is influenced by and influences world market conditions, cooperative game theory is employed in constructing a simulation model. Game theory models the interaction of two or more participants, or players, with conflicts of interest. In cooperative games, the returns, or payoffs, to the players are increased by the coordination of the players' strategies. Players are able to communicate without distortions, and binding agreements are possible in the course of preplay negotiations.

Application of cooperative game theory to EEP requires definition of the players expected payoffs from cooperation and their threat strategies, or what they obtain in the absence of cooperation. In the bargaining models, a single firm is chosen to handle all EEP wheat exports. It is the only eligible receiver of EEP bonus payments in-kind. This simplifying assumption reflects the complexity and multiplicity of solutions which recognition of multiple individual competing grain-exporting firms, multinational and domestic, would introduce into an EEP bargaining model and the lack of firm-specific data required to incorporate the firms individually in the model.

This assumption limits the analysis to two extreme characterizations of industry behavior: monopolist and price taker. The assumption of monopoly allows the firm to obtain positive profits on EEP sales in a two-stage bargaining game. In one stage the monopolist and the targeted country bargain over the EEP sales price. In the second stage the monopolist and the CCC bargain over the EEP bonus. Because the monopoly results of the simulations are qualitatively similar to the competitive firm case, only the latter results are discussed in detail. The reader

[1] Bonus certificates issued before 2 Sep. 1986 specify the type of commodity available to the certificate holder. For example, bonuses paid on EEP sales of wheat before that date were paid only in wheat. Since that time generic certificates have been issued. These generic certificates may be exchanged for any commodity available in CCC stocks or may be sold to be used by producers as payment for outstanding CCC loans. Because the empirical model developed here is for the early fall of 1985 and the winter of 1986, the quantity equivalent of the EEP bonus is found by dividing the total bonus value by the market price for wheat.

interested in the outcomes under the assumption of monopolistic firm behavior is referred to Hillberg.

For the price-taking firm, EEP negotiations are characterized as a bargaining game between the Commodity Credit Corporation and the targeted country subject to the firm's zero profit condition:

$$(1) \qquad P_{ush} + B_h - P_{usus} - T_{ush} = 0,$$

where P_{ush} is EEP sales price of U.S. wheat in targeted country h, B_h is bonus per unit on EEP sales to targeted country h, P_{usus} is commercial price of U.S. wheat in the U.S., and T_{ush} is per unit transportation costs on U.S. wheat to targeted country h.

Expected payoffs to CCC are complicated by the number of objectives pursued by that agency and their conflicting nature. A weighted CCC objective function is introduced in order to capture the individual EEP goals and their relative importance. The individual components of this objective function, based on interviews with government officials responsible for operation of the program, are assumed to be the value of EC sales lost because of an EEP agreement, the value of the EEP sale, and CCC costs on EEP payment in-kind bonuses. Combining these components, the CCC weighted objective function is

$$(2) \qquad G_h = w_{ec}[P_{ech}X_{ech}] + w_x[P_{ush}X_{ush}] - w_c[(B_hX_{ush}/P_{usus})*OP],$$

where G_h is CCC benefits from EEP sales to targeted country h; w_{ec}, weight placed by CCC on displaced EC wheat sales value; P_{ech}, price of EC wheat in targeted country h in the absence of EEP; X_{ech}, exports of EC wheat to targeted country h in the absence of EEP; w_x, weight placed by CCC on EEP export value; P_{ush} EEP sales price of U.S. wheat in targeted country h; X_{ush}, sales quantity supplied to targeted country h upon which per unit EEP bonus is paid; w_c, weight placed by CCC on changes in storage costs; B_h, bonus per unit on EEP sales to targeted country h; P_{usus}, commercial price of U.S. wheat in the United States, and OP is per unit value of wheat in CCC storage.

Presence of displaced European Community sales value as the first term, $P_{ech}X_{ech}$, in the objective function shown above reflects the assumption that the EC is the sole target of U.S. allegations of unfair trade practices in operation of the Export Enhancement Program. This view is reflected in Secretary Block's announcement of the program (Block). The second term, $P_{ush}X_{ush}$, implies that any sales revenue achieved under an EEP transaction in the targeted country is considered to offer the U.S. export additionality as defined in the program guidelines above.

The third term, $((B_hX_{ush})/P_{usus})*OP$, is the budgetary cost to CCC of the EEP.[2] Wheat in CCC inventories has a value as given by its role as a government asset purchased under agricultural price support programs. But storage costs are also incurred by CCC if grain is held in government storage rather than released into less restricted channels of supply in the form of an EEP bonus. Therefore, the value of government stocks, OP, is calculated as the present value of any future selling price of the grain, which here is considered to be the CCC loan rate, less the present value of storage costs incurred until the stocks may by sold by the government. The total cost of the EEP then is the quantity equivalent of the bonus multiplied by the value of CCC stocks which, assuming a five-year storage period caused by record stock levels, was calculated to be slightly less than one-half the prevailing market price during the period simulated.

The threat payoff to the CCC of not participating in an EEP sale with a particular target is zero, or, $G_h^* = 0$. This assumes that the only damage the two players can inflict on each other is to refuse to trade.

The targeted country is assumed to weigh expenditures for purchase of wheat under EEP against importing from commercial sources. In order to capture these purchases in commercial and EEP markets, a technique employed by Roth (1986) is adopted. Roth models consumer demand in a developing country by permitting "commodity purchases in two structurally different markets—a private market, where prices and quantities are unrestricted, and the official market, where prices are fixed and quantity demanded is constrained by market rations" (Roth 1986, p. 251). In the EEP model, parallels are drawn between Roth's private market and commercial purchases of wheat from domestic and foreign sources and between Roth's official market and the market for EEP sales. Using a Stone-Geary utility function, the targeted coun-

[2] Since the inception of the Export Enhancement Program, the program guidelines have been legislatively amended to mandate program expenditure levels. Prior to this legislation, USDA exercised discretion over the lower bound on EEP spending. The Food Security Act of 1985 and the Food Security Improvements Act of 1986 authorized minimum expenditures for EEP bonus commodities of \$1.0 billion for the period October 1985 through September 1988. In extending the EEP, the Ominbus Trade Act of 1988 set funding at \$2.5 billion for October 1985 to September 1990.

try assigns utility to its consumption of goods purchased in both markets, and it wishes to maximize this utility.[3] The targeted country's problem is stated as

$$(3)\quad \text{Maximize } U_h = \sum_k B_{kh} \log (C_{kh} - Z_{kh}) + B_{wh} \log (C_{wh} - Z_{wh}),$$

subject to

$$D_{wh} + X_{ush} \geq C_{wh}$$

$$\sum_k P_{kh}C_{kh} + P_{wh}D_{wh} + P_{ush}X_{ush} \leq Y,$$

where U_h is the utility of consumption in targeted country h;

B_{kh}, marginal budget share of good k consumption in targeted country h;

C_{kh}, consumption of good k in targeted country h;

Z_{kh}, subsistence consumption of good k in targeted country h;

B_{wh}, marginal budget share of wheat consumption in targeted country h;

C_{wh}, total wheat consumption by targeted country h;

Z_{wh}, subsistence consumption of wheat in targeted country h;

D_{wh}, commercial wheat consumption by targeted country h from both domestic and foreign sources;

X_{ush}, sales quantity supplied to targeted country h upon which per unit EEP bonus is paid;

P_{kh}, domestic price of good k in targeted country h;

P_{wh}, price of commercial wheat in targeted country h from both domestic and foreign sources;

P_{ush}, EEP sales price of U.S. wheat in targeted country h; and

Y is total consumption expenditures by targeted country h.

The constraints of the problem arise from the purchase of wheat in a commercial market covering both domestically produced and imported wheat and in a subsidized market provided under the Export Enhancement Program. The first restriction requires the level of wheat purchased in the two markets to equal or exceed the total quantity of wheat consumed by the targeted country. In the second constraint, expenditures on all goods, whether commercial or subsidized, may not exceed available targeted country income. A third constraint requiring the total quantity of EEP sales to be less than the maximum amount of wheat made available to the targeted country under EEP announcements was not included in the problem formulation for the following reason. Judged on a quarterly basis the maximum levels of allowable EEP sales determined by CCC are usually set at levels which are far higher than the potential for consumption in an individual target prohibited from re-exporting any surplus to other countries.

Because wheat is assumed to be a homogenous commodity in this formulation, if the EEP sales price is lower than the commercial import price of wheat, up to the maximum quantity of EEP wheat available to the targeted country is purchased before the country turns to commercial imports. In an Armington model with supplier-based product differentiation, the EEP would easily replace U.S. commercial wheat; but it would have more difficulty replacing rival suppliers' wheat. Thus, the formulation presented here should be viewed as revealing the maximum displacement of other countries' wheat trade by EEP.

Given the above formulation, an expenditure function is derived. Taking into account consumption of domestic production and the possibility of food aid commitments and long-term agreements continuing some quantity of restricted imports, $\bar{D}_{wh}$, the targeted country's expenditure function for subsidized EEP purchases and constrained commercial expenditures is

$$(4)\quad E_h = B_{wh}\,[Y - \sum_k P_{kh}Z_{kh} - P_{ush}Z_{wh} + \bar{D}_{wh}\,(P_{ush} - P_{wh})] + P_{ush}Z_{wh} - P_{ush}\bar{D}_{wh} + P_{wh}\bar{D}_{wh}.$$

The components of expenditure are the share of discretionary income claimed by imports of wheat plus the subsistence level of wheat imports by the targeted country as represented by the first and second terms. The final two terms represent the additional expenditures incurred by the targeted country in choosing to continue some level of imports from the higher priced non-EEP markets.

The threat strategy available to the targeted country is to purchase all wheat in commercial channels. This yields the familiar LES expenditure function, denoted E_h^*, as the targeted

[3] This utility function has two advantages for this problem. First, it allows a separation between the EEP market and the commercial market. Second, it yields a linear expenditure function which eases solution of the Nash bargaining problem.

country's threat payoff function.

The expected payoff functions and threat strategies for the CCC and the targeted country are employed to define the set of feasible EEP agreements. The bargaining problem is to find a unique outcome within the set which will define whether an EEP sale occurs and at what subsidy level. Nash provides a mechanism for determining this unique point which requires the distribution of payoffs under agreement to conform to certain prespecified criteria or axioms. The Nash solution assumes that cardinal utility-maximizing players of equal bargaining skill have initial endowments and preferences which define an area of mutual gain from bargaining. Any extension or reduction of this area can take place only if the unique solution is included in the revised area.

For the EEP bargaining game, the Nash bargaining problem is stated as

$$(5) \quad \underset{B_h}{\text{MAXIMIZE}}\ (G_h - G_h^*)*(E_h^* - E_h),$$

where G_h, E_h are expected payoffs to the CCC and the targeted country, respectively, under cooperation; and G_h^*, E_h^*, "threat strategy," what the CCC and the targeted country, respectively, obtain in the absence of cooperation. As can be seen, the function forms a mapping of parabolas. Maximizing this function determines a unique point on the boundary of the feasible set of outcomes where a parabola is tangent to the boundary. Applications of this model in empirical wage negotiations research suggest that the Nash solution is able to explain the behavior of bargaining entities such as firms and labor unions and not just the behavior of individuals as studied in experimental work (Bognanno and Dworkin, de Menil, Roth 1979, Siegel and Fouraker).

Two components then determine the EEP bonus when the Nash solution is applied. The first component is one-half the bonus which would make the CCC indifferent between returns under cooperation and returns under the threat strategy. Similarly, the second component is one-half the bonus which would make the targeted country indifferent between purchasing under an EEP agreement and purchasing solely in the commercial markets.

A spatial price equilibrium model is solved iteratively with the Nash bargaining models for each target to allow the simultaneous determination of EEP and non-EEP trade flows and prices. Quarterly trade elasticities are combined with base price and quantity data to construct linear non-EEP excess demand and excess supply schedules for all the regions included in the model except the United States.

Specification of U.S. excess supply involves subtracting five components of demand for U.S. wheat from a fixed quarterly supply. Individual schedules determine food and feed demand, farmer-owned reserve stockholding, CCC stockholding, and private stockholding. The fifth demand component, that of EEP, is determined by the bargaining models. The purpose of this more detailed representation of the U.S. wheat market is to include a mechanism which releases EEP bonus commodities from CCC storage where stocks are subject to legislated release rules into less regulated channels of supply. In this manner, the payment of EEP bonuses in-kind from CCC storage, rather than in cash, is recognized. Additionally, the interaction of the EEP with domestic policy provisions such as CCC loan rates is incorporated in the model. In the empirical results which follow, the level of U.S. policy instruments, especially the loan rate, is critical to the effects of the program.

Base Solutions

Determination of a base solution for the EEP model requires one further set of model parameters. Because the priorities placed by the CCC on the targeting, additionality, and cost components of the payoff function are not known with certainty, EEP model simulations are used to determine sets of weights for the CCC payoff functions. Three different rules were applied in the search for these weights. First, the weight placed on the value of the EEP sale was set at zero, leaving the CCC with the combined objectives of displacing EC sales value in the targeted country and controlling program costs. Second, the value of displaced EC sales received a zero weight. In this case, the CCC's interests turn toward increasing the EEP sales value to the targeted country in addition to controlling program costs. Third, equal values were placed on the weight for displaced EC sales in the targeted country and on the weight for EEP sales to the targeted country.

Table 1 compares actual data with the base solution results chosen from these three simulations. The base solution weighting schemes are selected based on their ability to predict the success and the failure of EEP sales to individual targets and the similarity of the weighting

Table 1. Bargaining Game Base Solutions

	Actual	Targeting EC	Actual	Increased EEP Sales
	October to December 1985		January to March 1986	
Algeria				
Price	111.00	108.69	105.00	129.36
Quantity	500	797	500	504
Bonus	45.54	45.40	23.09	23.10
W_{ec}		.231		.000
W_x		.000		.157
W_c		.769		.843
Morocco				
Price	131.20	127.76	123.80	122.93
Quantity	300	414	460	336
Bonus	20.57	20.60	23.85	23.80
W_{ec}		.119		.000
W_x		.000		.173
W_c		.881		.827
Turkey				
Price	126.81	No	123.14	No
Quantity	450	Agreement	57	Agreement
Bonus	27.17		18.32	
Zaire				
Price			127.29	129.13
Quantity			20	47
Bonus			25.25	25.10
W_{ec}				.000
W_x				.178
W_c				.822
Philippines				
Price			128.75	126.50
Quantity			152	220
Bonus			22.03	22.00
W_{ec}				.000
W_x				.158
W_c				.842
Total Quantity	1,250	1,211	1,189	1,107

Source of actual data: GAO.

schemes across targets.[4] The two quarters of program operation simulated, October to December 1985 and January to March 1986, are the first and second quarters in which EEP sales to multiple targeted countries were completed.

Two separate weighting schemes were chosen to determine the base solutions in the quarters under study. For October to December 1985, the CCC is assumed to weigh the benefits of displacing EC sales value in the targeted country against the costs of providing bonus commodities. For January to March 1986, the base solution assumes that the CCC desires to increase EEP sales value to the targeted country while controlling program costs. The passage of legislation mandating minimum annual expenditures on EEP in late December of 1985 supports the empirical results of these models that CCC program objectives shifted during the quarters under study from targeting EC markets to increasing EEP sales value wherever possible.

While the base solutions in table 1 are quite accurate in their estimates of the EEP bonus levels for the individual targets participating in model results, the EEP price tends to be underestimated in the October to December 1985 quarter and the EEP quantities are overestimated in both quarters. The low estimate of the EEP price indicates that the zero profit condition applied to the exporting firm is inappropriate for the October to December 1985 quarter. Comparison of simulation results with actual data indicates pos-

[4] Each of the simulations was unable to predict the EEP sale completed with Turkey without assigning the country lower payoffs than it would achieve in the absence of a sale. A very high trade elasticity was calculated for Turkey because its imports were small relative to its domestic production of wheat. This high elasticity caused Turkey to respond to the lower EEP price by purchasing a much greater quantity of imports such that the level of total expenditures rose. Under the assumptions of the linear expenditure system, this increase in expenditures leads to a decline in utility. For a more complete discussion of the derivation of CCC weights, see Hillberg.

itive firm profits of approximately $2.40 per ton on sales to Algeria and $3.50 per ton on sales to Morocco. These results suggest that the firms had some influence over the EEP price which is understated in the competitive model. The monopoly bargaining models for this same period overstate the exporting firm's influence. Results for the quarter January to March 1986 show that the estimates of the subsidized price are no longer uniformly lower than the actual EEP prices.

The difficulty of the model in its prediction of the quantities shipped under the EEP lies with the lag between purchase and shipments of wheat in international trade. Delivery dates cited for a subset of EEP shipments (GAO) indicate that the three-month lag between purchase and shipping employed in the model is representative on average, but instances of shipment in the same quarter as purchase or with a two-quarter lag are known. Combining the quarterly estimates reduces the magnitude of the error.

When summed over all the targeted countries participating in EEP sales, the bargaining models show a 9% overestimate and a 6% underestimate of the total value of EEP bonuses awarded for October to December 1985 and January to March 1986, respectively. The total quantity of EEP shipments made during these quarters was underestimated by the bargaining models with errors of 3% and 7%, respectively.

World Wheat Market Impacts of the EEP

The impact of the program is estimated through a comparison of the EEP base solution with simulation of the spatial price equilibrium model assuming the absence of the program. For October to December 1985, although 1.2 million metric tons are shipped under the EEP, world trade increases by only 110,000 metric tons, or less than 1% compared with model results without the EEP. During January to March 1986, increases in world trade are also held at less than 1%.

For the United States, October to December 1985 total wheat exports rose by 3% from 5.8 to 6.0 million metric tons because of the EEP. U.S. wheat exports for January to March 1986 rose by 2%, from 5.4 to 5.5 million metric tons. These results then indicate a high rate of displacement of commercial sales by subsidized sales in both quarters under study. For the targeted countries participating in successful EEP sales, the percentage increases in total imports are as follows: Algeria (+6% to +8%), Morocco (+7% to +10%), Zaire (+2%), and the Philippines (+3%).

In terms of trade flows, the model results show the United States leaving markets in developed Asia and Africa and moving into the targeted countries' markets. Displacement of the EC by the United States in North African markets is compensated by increased EC trade with the USSR and other African markets. As the EC displaces Australia in the Soviet market, Australia ships increasingly to the developed Asia market given up by the United States.

The U.S. price effects of the EEP for October to December 1985 are slightly positive as the border price rises from $135.31 to $135.56 per ton. Where approximately 330,000 metric tons of EEP bonus wheat are awarded during the quarter, ending CCC stocks are reduced by only 45,000 metric tons because of additional CCC loan forfeitures of 285,000 metric tons. Farmer-owned reserve stocks remain unchanged by the EEP, while free stocks decline by 120,000 metric tons. Domestic demand for food and feed wheat is lower by 3,000 metric tons. The results for January to March 1986 show a similar pattern as the U.S. border price rises from $133.72 to $133.94.

The increases in the U.S. export volume and border price lead to a rise in export revenues of 3% for October to December 1985, as shown in table 2. However, if these revenues of $817 million are adjusted for the cost of the bonus commodities to CCC, $20.2 million, the increase in U.S. export revenues due to the EEP is less than

Table 2. Estimated Export Revenues and Subsidy Costs

	No EEP	Base Solutions
	------ ($ million)	------
October to December 1985		
U.S. Total Revenues		817.2
Subsidy Costs		20.2
Adjusted Revenues	792.7	797.0
Canada	375.8	375.8
EC	506.5	499.1
Australia	674.9	670.0
Argentina	371.6	370.2
January to March 1986		
U.S. Total Revenues		740.2
Subsidy Costs		11.7
Adjusted Revenues	722.5	728.4
Canada	464.4	457.6
EC	302.4	297.1
Australia	597.0	598.9
Argentina	115.6	115.9

1%. For January to March 1986, the model also suggests a less than 1% increase in U.S. export revenues. If the costs of the additional CCC loan forfeitures are also recognized as a cost of the EEP, U.S. export revenues adjusted for program costs fall below levels achieved in the absence of the program.

According to the model results, the effect on other exporters of the EEP is also very slight. Declines of only 1% in European Community export volume are shown for both of the quarters under study. Combined with slight declines in border prices, EC export revenues fall by almost 2% in each quarter.

For Canada, Australia, and Argentina, the negative effects of the EEP on export revenue are less than 1% for October to December 1985. For January to March 1986, results also indicate very small changes in export revenue for this group of exporters. However, in contrast to the previous quarter's results, these changes in revenue, while again less than 1%, are now positive for Australia and Argentina. These contradictory results are caused by the abrupt changes in trade flows which occur in simulations using spatial price equilibrium models. The magnitude of these changes suggest very small effects of the EEP on Canada, Australia, and Argentina during the periods under study whether in a positive or negative direction.

Lowered Loan Rate Simulation

The simultaneous release of EEP bonus wheat and acquisition of loan forfeitures by the CCC raises the question of how the program might have operated if the lower loan rate legislated for the 1986 crop year were in effect during the quarter January to March 1986. In order to address this question, two further model simulations are run. First, the loan rate is lowered from \$147.00 to \$114.00 per ton, and corresponding downward adjustments to the price expectations of commercial stockholders are made. Thus, solutions with a lowered loan rate but without the EEP are obtained. The second simulation adds the EEP to the lowered loan rate environment.

With only the lowered loan rate, U.S. wheat exports increase by 2.0 million metric tons or 37% during the quarter. Approximately 1.3 million metric tons of the increase in U.S. exports come from what may be considered a one-time reduction in private stock levels because of altered price expectations. The price of wheat in the United States is \$11.23 per ton lower, falling from \$133.72 to \$122.49 per ton. Competing exporters respond to lowered market prices with a 1.0 million metric ton reduction in wheat exports.

U.S. exports rise by an additional 100,000 metric tons because of the EEP in combination with a lowered loan rate. Adjusting for an estimated one-time downward adjustment in private stocks, lowering the loan rate alone increased U.S. exports by 13%, while the EEP created an additional 2% increase in exports. The lower loan rate prevents the acquisition of additional CCC stocks in the form of loan forfeitures. Thus, the release of 184,000 metric tons in bonus commodities from CCC storage leads to an additional fall in the U.S. border price from \$122.49 to \$122.31 per ton. The net effect of these changes is to reduce U.S. export revenues adjusted for the cost of the subsidies below levels achieved in the absence of EEP. Table 3 shows this decline of U.S. export revenues due to the EEP from \$908 million to \$906 million.

For all the other exporters—the EC, Canada, Australia, and Argentina—lower export quantities are combined with declining border prices under the lowered loan rate and the EEP. The lowered loan rate alone leads to a 16% decline in the level of other exporters' revenues from wheat exports. The EEP further reduces competing exporters' revenues, but by less than 1%.

Conclusions

This study employed Nash bargaining models to analyze the impact of the Export Enhancement Program. The results suggest that this model is able to explain the EEP prices, bonuses, and quantities for the period October 1985 to March 1986, although the estimates of quantity are subject to greater error. Examination of the EEP

Table 3. Comparison of an EEP Under a Lowered Loan Rate and the Absence of EEP with a Lowered Loan Rate: Estimated Export Revenues

	January to March 1986		
	No EEP	EEP	Change
	---- (\$ million) ----		
United States	908.1	906.9	
Canada	378.5	377.1	
EC	234.1	233.0	
Australia	526.6	525.1	
Argentina	104.4	104.2	

program suggests a change in CCC objectives between October to December 1985 and January to March 1986. The earlier quarter shows a stronger desire to complete sales in markets supplied by the European Community, while the later quarter indicates a greater priority placed on expanding EEP sales to all targets.

The benefits of the Export Enhancement Program to the United States during the quarters studied were estimated to be small and relied on the simultaneous release of EEP bonus wheat from CCC storage and acquisition of loan forfeitures by the CCC. Measured in terms of export revenues adjusted for the costs of the EEP subsidies, these benefits of a less than 1% increase in U.S. revenues disappear if the costs of the additional CCC stocks acquisitions are incorporated in the model as a cost of EEP operation. In the presence of a lower loan rate, the lack of additional loan forfeiture acquisitions by the CCC leads to U.S. export revenues lower than they are estimated to be in the absence of the program.

Given the program as operated in this period, these scenarios suggest that the fall in the CCC loan rate caused a far larger increase in U.S. wheat exports than did the EEP. Adjusting for an estimated one-time downward adjustment in private stocks, lowering the loan rate alone increased U.S. exports by 13% while the EEP created an added 2% increase in exports. Other exporters must adjust to marked changes in trade flow patterns. However, the impact of the EEP on their export levels and border prices during these quarters is very slight, although generally in a negative direction. The impact of the lowered loan rate on these countries is far more significant.

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Valuing Trade-Offs between Net Returns and Stewardship Practices: The Case of Soil Conservation in Saskatchewan

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In this paper, a trade-off function between net returns and soil quality is developed for farmers in southwestern Saskatchewan using a Markov decision model. The results show that farmers who are concerned with soil levels or stewardship employ chem-fallow more often at lower soil moisture levels and also tend to crop more intensively to conserve soil. The major conclusion is that concern for soil quality, as documented by some researchers, does have practical significance in changing agronomic practices; but, when soil is relatively deep, it takes a fairly substantial concern about soil quality before it is possible to distinguish clearly the agricultural practices of farmers who are truly concerned with stewardship from those who are not.

Key words: dynamic programming, economic trade-off, soil conservation.

Research indicates that agricultural producers do not behave solely as profit maximizers, but that they usually maximize some form of utility function (Lin, Dean, and Moore; Van Kooten, Schoney, and Hayward). As Paterson discovered, soil stewardship is a priority for many farmers and should be included in the utility function. Stewardship implies that the soil resource be used so that long-term productivity is not diminished; however, in practice, interpretation of the term "stewardship" varies among individuals. The purpose of this study is to investigate the relevance of stewardship to farming practices and, in particular, to investigate the ability and willingness of individual farmers to sacrifice profits for soil quality. Therefore, soil quality is explicitly included in the farmer's utility function along with profit, and a trade-off function between soil quality and net returns is constructed in a dynamic framework.

An example of the approach used here is provided by Thampapillai and Sinden (TS) who determine trade-offs for multiple objective planning in northern New South Wales in Australia. Their model consists of a function with two objectives—a monetary objective, income maximization, and a nonmonetary objective, maintenance of environmental quality. The trade-off function was derived by changing the relative weights on these objectives. Unlike TS, who employed deterministic linear programming, we use a (dynamic) Markov decision model here to study trade-offs among objectives.

Our focus is on how optimal farm management practices are affected by various levels of concern for stewardship. We assume that agricultural producers in the brown soil zone of southwestern Saskatchewan maximize discounted utility as a function of net returns and soil quality, where soil quality is measured by soil depth. We examine flexcropping of spring wheat in conjunction with either tillage fallow or chem-fallow for moisture conservation. As opposed to a fixed crop rotation, such as the dominant two-year, wheat-fallow rotation in the study region, the flexcrop strategy relies on a measure of spring soil moisture to determine whether to plant or fallow (Burt and Allison).

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The critical soil moisture level and, hence, the cropping strategy and extent of subsequent erosion are affected by stewardship concerns.

The following sections develop a theoretical foundation for the problem and describe the empirical model. Then, stochastic dynamic programming (SDP) is used to solve the Markov decision process and find the optimal flexcrop strategy under various weights for the two objectives in the utility function. A trade-off function between the attributes is developed and time paths of soil erosion under various weightings of the soil quality objective in the utility function are investigated.

Theory: Trade-off between Net Returns and Soil Quality

It is assumed that farmers maximize the discounted value of a multi-objective utility function. The parameters of the utility function are net returns (π) and soil quality (Q), where soil quality is synonymous with minimizing soil erosion (i.e., soil conservation).[1] As a practical matter, soil quality is converted into a money measure by determining the productive value of soil depth. A model for analyzing the trade-off between soil quality and profit is illustrated in figure 1. Soil quality is plotted along the al scissa while profits are plotted along the ord nate. Because erosion is a dynamic concept, bo the profit and soil quality axes can be expresse in present value terms.

Point A defines the initial distribution of pro its and conservation, i.e., soil quality or dept prior to any decision making on the part farmers. Curve GF is the transformation fronti or trade-off function. This envelope of feasib alternatives includes all possible farming stra egies, that is, agricultural practices or uses f the land over time. Along the frontier, the ma ginal rate of transformation (MRT) measures tl sacrifice of discounted profit for a unit increa in present value of soil quality. The MRT is d fined as

$$MRT = -d\pi/dQ = (\delta g/\delta Q)/(\delta g/\delta \pi),$$

where $g(\pi, Q)$ is a convex function, the tran formation locus.

An indifference map is superimposed on tl transformation curve in figure 1. The farmer discounted utility function is expressed by is present value of utility (indifference) curves which the marginal rate of substitution (MR between soil quality and profits is defined as

$$MRS = -d\pi/dQ = (\delta U/\delta Q)/(\delta U/\delta \pi).$$

Farmers attain their highest indifference conto at point E, where $MRT = MRS$ in the feasib set. The line (MM') passing through E and ta gent to both the transformation locus ar

[1] Soil conservation is a shift of extraction rates toward the future, while soil depletion or erosion is a shift of use rates toward the present (Ciriacy-Wantrup).

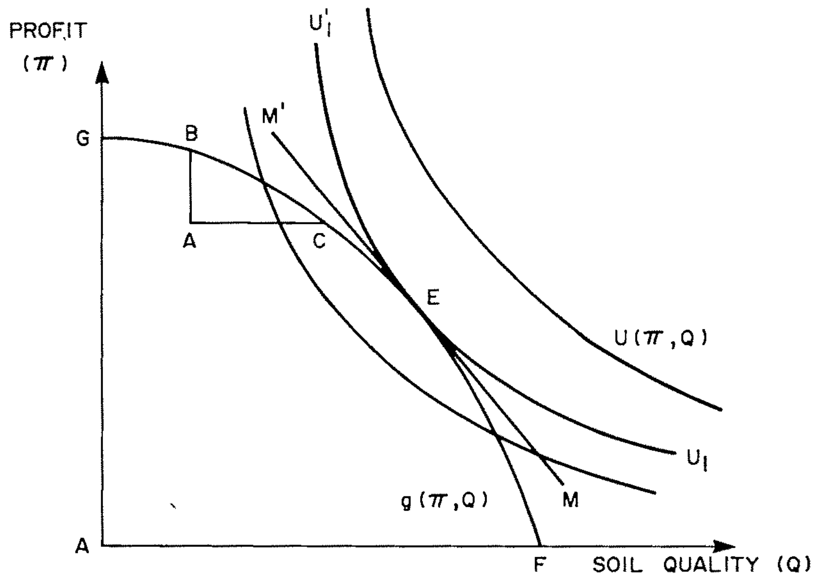

Figure 1. Trade-off function for profit and soil quality

U_1U_1' is important because the negative slope of MM' indicates the relative marginal values of π and Q held by the decision maker. We refer to the marginal trade-off of Q for the other objective as a weight. Therefore, the slope of U_1U_1' at point E is the negative of the ratio of the soil quality weight in the utility function to the weight for profits. If the latter weight is one and the soil quality weight is λ, the slope of MM' is then $-\lambda/1 = -\lambda$. In equilibrium, therefore, $MRT = MRS = \lambda$. By choosing different values of λ in a dynamic decision model, it is possible to find GF.

Given the dynamic nature of soil erosion and cropping systems, a dynamic optimization model is used to determine the trade-off function between net returns and soil depth. The objective function is

$$(1) \qquad \sum_{t=0}^{T} U_t(\pi_t, Q_t)\, \beta^t,$$

where $\beta = 1/(1 + r)$ is the discount factor, with rate of discount r, and T is the length of the planning horizon. Net returns depend upon the choices available to the decision maker. In the model, farmers can select from the following choices (d) at spring planting time: (a) plant wheat; (b) summerfallow to store soil moisture for next year's crop, using tillage operations to keep fields free of weeds; or (c) use chem-fallow to store moisture and protect the soil from eroding to the extent it does under tillage fallow. The state variables in the model are soil depth (D) and available soil moisture (M) at spring planting time (early May).

The utility function is assumed to be strongly separable in net returns and soil quality. After a monotonic transformation of the utility function, the objective function (1) can be written as

$$(2) \qquad \sum_{t=0}^{T} [(1 - \lambda)\, \pi_t + \lambda\, Q_t]\, \beta^t,$$

where $0 \leq \lambda \leq 1$ is the utility weight attached to the soil quality objective. Soil quality is a function of the state variables, moisture and soil depth; that is $Q(D_t, M_t)$.[2] The soil quality function itself remains invariant with respect to time.

The objective function (1) is maximized subject to the following state transformation equations:

$$(3) \qquad D_{t+1} = D_t - h(d_t, D_t), \text{ and}$$

$$(4) \qquad M_{t+1} = M_t + g(d_t, M_t).$$

Dynamic constraint (3) states that soil depth in the next period is equal to the current period value minus the soil extracted by farming operations (tillage fallow, chem-fallow, or crop). Transformation equation (4) states that available soil moisture next year is related to current soil moisture and the agronomic decision either to exploit moisture (crop) or enhance moisture (tillage fallow or chem-fallow).

Both the state variables—available soil moisture at planting time and soil depth—are stochastic variables. Soil moisture is stochastic because annual precipitation is unpredictable. However, the distribution of moisture available at the beginning of a crop year is dependent on the decision in the preceding year. Similarly, the soil erosion experienced in a given year depends on the agronomic decision taken, with uncertainty attributed to vagaries in weather conditions. Unlike soil moisture, however, soil depth is continually declining in random fashion because soil regeneration is considered insignificant.

A particular state is defined as a pair of observations on soil moisture and soil depth. Hence, the SDP recursive equation can be written as

$$(5) \qquad V_t(i) = \max_{d(t)} E[R^d(i) + \beta \sum_{j=1}^{m} p^d(i, j)\, V_{t+1}(j)],$$

where $V_t(i)$ is the discounted value of future net returns, given the state variable is at level i at the beginning of the T-stage process,[3] $V_{t+1}(j)$ is the discounted value of future net returns over the remaining $T - 1$ years of a T-year horizon, given the state conditions are at level j and that the optimal path is followed; $p^d(i, j)$ is the probability of moving from state i to state j, given that alternative d is chosen; $R^d(i)$ is the reward in state i, given decision d; and there are a total of m states. Equation (5) is solved recursively to yield the optimal solution.

Data for the Study Region

The data used in the study come from the Innovative Acres Project administered by the Department of Soil Science at the University of

[2] This relationship is described further in the empirical section.

[3] Each of a finite number of states consists of a combination of some level of soil moisture and soil depth.

Saskatchewan. The major objectives of this project are to maximize crop productivity and sustain high soil quality through the implementation of water-efficient farming practices. For each Saskatchewan farm in the program, data have been collected from an average of twenty-four plots spread over two research fields; but, for each plot, data are only available for a period of four years. (The few years of available data, unfortunately, will affect the generality of the conclusions.) Only data from the eleven Innovative Acres farms located in the brown soil zone of Saskatchewan are used in this study.

The following variables are included in the data; (*a*) the depth of the *A* and *B* soil horizons (solum depth), (*b*) the level of available soil moisture at planting time, and (*c*) the type of crop seeded and its yield. The data include observations of both conventional and chemical fallow, and the dominant crop in the region is hard spring wheat. The average wheat yield for the farms in the study area is 1,622.87 kilograms per hectare (24.1 bushels per acre), which accords with historical yields for wheat. The ten-year (1977–86) average spring wheat yield in the region was 1,649.93 kg/ha (24.5 bu/ac). Further information regarding the data is found in Weisensel.

If no crop is grown, then yield is zero and only a cost of fallowing is incurred. The cost of the fallowing strategy depends upon whether tillage fallow or chem-fallow is employed. Cost of production data, which is based on total variable costs of production, was obtained from Schoney and is provided in table 1. The cost of chem-fallow is from the Innovative Acres data, but it is comparable to the other cost data. Adjustments were made to the cost structure as solum depth changed in order to keep production on the expansion path (see Weisensel). In addition, the costs of chem-fallow and tillage fallow are adjusted to account for lower seeding costs on fallow as opposed to stubble (table 1). However, because the model does not include decisions regarding optimal investment in machinery and equipment, it is assumed that fixed costs remain the same over the length of the planning horizon. Thus, the focus is on variable profits.

Table 1. Cost of Production Data for Brown Soil Zone of Saskatchewan

Description	Cost
	($Cdn/hectare)
Wheat on fallow	98.60
Wheat on stubble	112.73
Cost adjustment for seeding on summer-fallow vs. stubble	14.13
Tillage summer-fallow	20.85
Chem-fallow	47.42

Source: Schoney and Innovative Acres annual reports.

Estimated Yield Function and the Measurement of Soil Quality

The net return (variable profit) in any given year is the price of output (P) multiplied by yield (Y) minus the cost of the activity (c). Yield is a function of the state variables solum depth (D) and available soil moisture (M) at spring planting time. Of course, yield is zero if the land is not cropped. The yield function is stationary, price is fixed, and the cost or production depends only on the decision (d), which is fixed for each activity. Thus, net returns can be written as

$$\pi_t(d_t, M_t, d_t) = P \cdot Y(D_t, M_t, d_t) - c(d_t).$$

This expression is then substituted into (2).

The yield function is assumed to take a modified Mitscherlich-Spillman functional form:

$$Y = a + b\,(1 - R_1^D)\,(1 - R_2^M),$$

where a, b, R_1, and R_2 are parameters to be estimated, D is centimeters of solum depth, and M is centimeters of available soil moisture.[4] The estimated relationship is

$$\begin{aligned}(6)\quad Y = \underset{(0.27)}{84.02} + \underset{(7.67)}{2808.1}(1 - \underset{(2.16)}{0.634}^D)\\ \cdot(1 - \underset{(28.3)}{0.926}^M),\ R^2 = 0.22,\end{aligned}$$

where the t-statistics are provided in parentheses and there are 484 observations. Equation (6) represents the expected yield function for farmers, assuming that solum depth and available soil moisture are known at planting time.

The soil quality objective is made commensurable with net returns by specifying the value of soil in monetary terms. A dollar value for soil quality is obtained by integrating the value of marginal product (VMP) curve for solum depth [obtained from (6)] between zero and the amount of solum depth in the field. The value of the marginal product of solum depth is

[4] Other functional forms were also examined, but this form gave the best results from both a statistical and agronomic viewpoint (Weisensel).

$$VMP = P\ \delta Y/\delta D = P[-b\ \ln R_1\ R_1^D\ (1 - R_2^M)].$$

Suppose q is a given solum depth. Then the value of q to the producer, say Q, is found by integration.

$$\begin{aligned} Q &= \int_0^q VMP\ dD \\ &= \int_0^q [-P\ b\ \ln R_1\ R_1^D\ (1 - R_2^M)]dD \\ &= Pb(1 - R_2^M)\ (1 - R_1^q). \end{aligned}$$

In (7), Q measures the shadow value of soil quality and is our surrogate for soil quality in the utility function.

To reflect a distaste for fallow in the current period as opposed to planting a crop, the soil quality metric in the objective function is multiplied by a factor μ determined by the ratio of expected soil loss under the particular decision taken to the soil loss expected when land is cropped. Thus, if the decision is to crop, then the adjustment factor is 1.0; it is less than 1.0 for either of the fallow decisions (table 3).

Because the objective function (2) is separable in the two objectives, profit and soil quality, it can now be written as

$$(8)\quad \sum_{t=0}^{T} \{(1 - \lambda)\ P\ [84.02 + 2808.0\ (1 - 0.634^{D_t}) \cdot (1 - 0.926^{M_t}) - c(d_t)] + \lambda\ \mu\ P\ [2808.0\ (1 - 0.634^{D_t}) \cdot (1 - 0.926^{M_t})]\}.$$

Although the dual objectives are commensurable in expression (8), this does not imply that the agricultural producer considers \$1 of net return to be identical to \$1 from soil conservation. Rather, one can think of π as realized returns and Q as unrealized or psychological returns. This explains the similarity (but not equality) of expressions (6) and (7).

State Transformation Equations: The Transition Matrix

In the SDP model, the state transformation equations (3) and (4) are represented by a probability transition matrix giving the probability $P^d(i, j)$ of moving from state i in time t to state j in time $t + 1$ given that decision d was made at time t. In order to compute the entire transition matrix, a transition matrix for each of the state variables, soil moisture and solum depth, must first be calculated.

The following procedure was employed to calculate the soil moisture transition probabilities. Spring soil moisture in the year following a spring wheat year is regressed on spring soil moisture of the preceding crop year. The data on soil moisture are described in detail by Chinthammit. Similarly, spring soil moisture in the year following fallow is regressed on spring soil moisture of the fallow year for each of tillage fallow and chemical fallow. A double logarithmic functional form was used for the three regressions. The results are as follows:

(9a) Spring wheat:
$$\ln M_t = \underset{(12.33)}{1.6017} + \underset{(4.07)}{0.2271} \ln M_{t-1},$$
$$R^2 = 0.0434,\ SEE = 0.5075, \text{ and } n = 367;$$

(9b) Regular fallow:
$$\ln M_t = \underset{(18.66)}{2.0212} + \underset{(4.95)}{0.2286} \ln M_{t-1}$$
$$R^2 = 0.1052,\ SEE = 0.3075, \text{ and } n = 210;$$

(9c) Chemical fallow:
$$\ln M_t = \underset{(10.71)}{1.9693} + \underset{(3.04)}{0.2587} \ln M_{t-1}$$
$$R^2 = 0.1371,\ SEE = 0.3301, \text{ and } n = 60.$$

Here, SEE is the standard error of the estimate, n is the number of observations, and the t-statistics are provided in parentheses.

As expected, the intercept and slope for the spring wheat equation are lower than for both the fallow equations. A Breusch-Pagan test was employed to test for heteroscedasticity in the soil moisture state equations. The null hypothesis that the error term is independently and identically distributed could not be rejected at the 95% level.

Soil moisture is divided into ten discrete intervals in the SDP model. The intervals and their midpoints are provided in table 2. The probability transition matrix has a dimension of 30 by 10 to account for the three alternatives—tillage fallow (F), chem-fallow (C), and planting spring wheat (W). The soil moisture transition matrix is constructed using the results in equations (9).

To illustrate the method used to construct the matrix, consider alternative W in the fifth state (i.e., row 15 of table 2). Substitute the soil moisture value of 11.25–the midpoint of soil moisture interval 5—in the right-hand-side of (9a). This gives an expected mean of 8.60 centimeters of moisture. Assuming soil moisture has

Table 2. Soil Moisture Transition Matrix

		Soil Moisture Interval States (period t + 1)									
M_t	d_t	1	2	3	4	5	6	7	8	9	10
1	*F*	.0001	.0661	.3599	.3470	.1568	.0508	.0142	.0038	.0001	.0012
0–2.5 cm	*C*	.0004	.1026	.3824	.3126	.1365	.0459	.0139	.0040	.0012	.0005
	W	.0735	.3928	.2962	.1375	.0574	.0239	.0102	.0045	.0021	.0019
2	*F*	.0000	.0101	.1479	.3151	.2716	.1497	.0656	.0255	.0093	.0052
2.5–5.0 cm	*C*	.0000	.0168	.1679	.3048	.2525	.1432	.0671	.0285	.0115	.0077
	W	.0261	.2561	.3058	.1970	.1054	.0534	.0269	.0137	.0071	.0085
3	*F*	.0000	.0035	.0800	.2440	.2823	.1985	.1068	.0495	.0211	.0143
5.0–7.5 cm	*C*	.0000	.0058	.0914	.2377	.2636	.1901	.1091	.0551	.0260	.0212
	W	.0150	.1954	.2871	.2149	.1290	.0716	.0388	.0211	.0116	.0155
4	*F*	.0000	.0016	.0497	.1916	.2685	.2214	.1364	.0710	.0335	.0263
7.5–10.0 cm	*C*	.0000	.0026	.0566	.1859	.2493	.2104	.1378	.0781	.0407	.0386
	W	.0101	.1595	.2681	.2214	.1431	.0844	.0481	.0273	.0155	.0225
5	*F*	.0000	.0009	.0336	.1539	.2487	.2309	.1572	.0893	.0455	.0400
10.0–12.5 cm	*C*	.0000	.0014	.0379	.1482	.2289	.2171	.1570	.0969	.0543	.0583
	W	.0075	.1353	.2512	.2231	.1525	.0940	.0557	.0326	.0191	.0290
6	*F*	.0000	.0005	.0240	.1263	.2285	.2331	.1719	.1047	.0567	.0543
12.5–15.0 cm	*C*	.0000	.0008	.0269	.1205	.2082	.2167	.1695	.1119	.0667	.0788
	W	.0058	.1177	.2364	.2225	.1590	.1016	.0620	.0372	.0223	.0355
7	*F*	.0000	.0003	.0179	.1055	.2094	.2310	.1821	.1174	.0669	.0695
15.0–17.5 cm	*C*	.0000	.0005	.0198	.0997	.1889	.2124	.1773	.1239	.0776	.0999
	W	.0047	.1042	.2234	.2207	.1637	.1077	.0674	.0413	.0252	.0417
8	*F*	.0000	.0002	.0137	.0893	.1921	.2266	.1890	.1280	.0762	.0858
17.5–20.0 cm	*C*	.0000	.0004	.0151	.0836	.1715	.2060	.1818	.1334	.0871	.0332
	W	.0039	.0935	.2120	.2182	.1670	.1128	.0720	.0450	.0279	.0477
9	*F*	.0000	.0002	.0108	.0765	.1766	.2208	.1935	.1369	.0846	.1001
20.0–22.5 cm	*C*	.0000	.0002	.0118	.0710	.1561	.1986	.1841	.1408	.0954	.1420
	W	.0033	.0849	.2018	.2154	.1694	.1170	.0761	.0483	.0304	.0534
10	*F*	.0000	.0001	.0077	.0610	.1550	.2100	.1972	.1480	.0963	.1247
>22.5 cm	*C*	.0000	.0002	.0082	.0558	.1349	.1858	.1843	.1494	.1066	.1748
	W	.0026	.0738	.1876	.2104	.1719	.1224	.0817	.0530	.0340	.0626
Soil moisture midpoints		1.25	3.75	6.25	8.75	11.25	13.75	16.25	18.75	21.25	25.27

Note: The alternative decisions in period t (d_t) are as follows: *F* is conventional fallow, *C* is chemical fallow, *W* is planting of spring wheat.

a log-normal distribution, with variance given by *SEE* (=0.5075), it is possible to determine the probability that soil moisture will fall into a particular interval next year given that a crop is grown this year. This process is repeated for each row; each row constitutes a probability distribution and thus must sum to 1.0. In table 2, both the rows and columns are unimodal or exhibit monotonicity, but there is some inconsistency in the last several columns of the transition table. However, this problem does not significantly affect the results because the differences in probabilities are small.

The solum depth transition matrix is constructed from the erosion estimates of table 3; the last column in table 3 gives the adjustment factors μ for a 10%–24% slope. The transition matrix is based on the assumption that the erosion estimates are normally distributed (Kiss, de Jong, and Rostad). Given the estimates and their standard deviations, distribution theory can be used to calculate each row of the matrix. For each initial state i at time t, the normal distribution was integrated over each interval j, where j is the corresponding value of the state variable in time period t + 1, using the rate of erosion associated with particular alternative d. The result is the probability of moving from state i to state j, given alternative d is chosen. Repeating this operation for all intervals j in row i will complete the first row of the transition matrix. To complete the remainder of the matrix, the distribution function must be integrated for all states i, over all intervals j, and for all alternatives d (Weisensel).

The solum depth transition matrix for a slope grade of 10%–24% is provided in table 4 with a format similar to the soil moisture matrix in table 2. The higher slope grade represents a serious risk of erosion; it is used here for illustrative purposes, although similar results hold for lower slope grades. The solum depth transition

Table 3. Estimated Annual Rates of Soil Erosion and the Adjustment Factor by Decision and Slope Grade Position

	0%–3%		3%–10%		10%–24%		
Crop	Erosion	Std Dev	Erosion	Std Dev	Erosion	Std Dev	μ[a]
			(tons per hectare per year)				
Wheat	7.5	2.6	8.7	2.9	15.5	5.2	1.00
	(0.61)[b]	(0.21)	(0.71)	(0.27)	(1.26)	(0.42)	
Fallow	38.5	13.4	45.3	15.1	80.4	26.8	0.19
	(3.13)	(1.09)	(3.68)	(1.23)	(6.53)	(2.18)	
Chem-fallow	14.3	5.00	16.9	5.60	29.9	9.96	0.52
	(1.16)	(0.41)	(1.37)	(0.46)	(2.43)	(0.81)	

[a]Adjustment factor calculated for a slope grade of 10%–24%.
[b]Figures in parentheses are estimates of soil erosion in millimeters per year, assuming a 15-centimeter hectare furrow slice of solum weighing 1,800 tons per hectare.

Table 4. Solum Depth Transition Matrix, Slope Grade 10%–24%

		Solum Depth Interval States (period $t+1$)							
M_t	d_t	1	2	3	4	5	6	7	8
	F	0.0056	0.0471	0.1887	0.3439	0.286	0.1085	0.0187	0.0015
1	C	0.0388	0.7203	0.2402	0.0007	0	0	0	0
	W	0.268	0.7319	0.0001	0	0	0	0	0
	F	0	0.0056	0.0471	0.1887	0.3439	0.286	0.1085	0.0187
2	C	0	0.0388	0.7203	0.2402	0.0007	0	0	0
	W	0	0.268	0.7319	0.0001	0	0	0	0
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Note: See table 2 for further explanation.

matrix, which is based on 20 centimeters (cm) of solum depth with 2-milimeter intervals, has dimensions 300 by 100 because, for every solum depth state, there are three possible alternatives. The majority of values in the matrix are zero because it is highly unlikely, even on high risk soils, that more than 2 to 3 centimeters of topsoil can be eroded in a single year. Furthermore, the model does not account for soil deposition or regeneration; thus, the probability of increasing solum depth is zero.

Every third row of the solum depth transition matrix is exactly the same except that it is shifted to the right one column. This result occurs between each row of the matrix (for the same alternative) is calculated using the same erosion estimate from table 3. Finally, solum depth cannot be eroded below zero. Because the probabilities in the bottom rows of the solum depth matrix must reflect this phenomenon, the final rows of the matrix are modified so that the probabilities in each row still add to one. This is done by calculating the probability of the 100th column as one minus the sum of the previous 99 columns for the given row. Because of the size of the solum depth transition matrix, the number of zeros in it and the similarity of the rows (except for the last several), only the first three rows and eight columns are shown in table 4.

The solum depth and moisture probabilities are assumed independent of each other. Therefore, the total transition matrix for the system is found by multiplying each entry for a given solum depth state by the row associated with a particular soil moisture state. The new states created in this way consist of a paired observation on solum depth and available spring soil moisture.

Optimal Flexcrop Strategies

Because soil is continually being eroded, value-iteration over a period of thirty years is used to solve the SDP problem. A price of $Cdn.128.52 per tonne ($3.50/bu) and erosion rates comparable to those for a 10%–24% slope are employed. Optimal strategies for different values of the soil quality weight, λ, and for different levels of available soil moisture and solum depth are determined. The present value of net returns

depends upon the level of soil moisture as well as solum depth. For a solum depth of 20 centimeters the present value of net returns for the strategy associated with $\lambda = 0.0$ (no weight on soil quality) increases from approximately $1,140 per hectare to $1,390 per hectare as available spring soil moisture increases from the lowest to the highest level; for $\lambda = 0.8$, the associated range is $1,050 per hectare to $1,340 per hectare.

The optimal strategies and critical soil moisture values also change as solum depth declines. For example, the strategy for a producer with $\lambda = 0.4$ is to employ tillage fallow whenever available soil moisture is below 2.5 centimeters, use chem-fallow when it is between 2.5 centimeters and 5.0 centimeters, and plant spring wheat whenever spring soil moisture is greater than 5.0 centimeters, but only when solum depth exceeds 12.8 centimeters. For solum depths between 4.4 and 12.8 centimeters, the optimal strategy is to employ chem-fallow whenever available soil moisture in the spring is below 5.0 centimeters and to plant wheat otherwise. Finally, if solum depth is below 4.4 centimeters, the optimal strategy is to employ chem-fallow if soil moisture is below 2.5 centimeters and plant wheat if it is above this level, at least until the present value of net returns becomes negative. No allowance is made for alternatives other than fallowing and planting of spring wheat. It is likely that land will be turned into pasture at low solum depth levels, although this was not investigated in the model.

In summary, the optimal strategies obtained from the Markov decision model indicate that a producer will employ chem-fallow as opposed to tillage or conventional fallow at higher values of λ.[5] For example, at 20 centimeters of soil, the farmer with $\lambda = 0.6$ will chem-fallow when soil moisture is less than 5.0 centimeters, while a producer with $\lambda = 0.0$ will employ tillage fallow whenever soil moisture is below 7.5 centimeters. Further, at lower solum depths, the farmer concerned with soil quality will tend to crop at lower levels of soil moisture and use chem-fallow more frequently compared with the producer who does not share this concern for soil quality.

The flexcrop results can be used to estimate how long it takes to erode a given amount of soil. Given an initial soil moisture level of 11.25 centimeters, flexcrop strategies take between 129 and 200 years to erode 32 centimeters of solum down to 4 centimeters, depending upon assumptions about the importance farmers place on solum depth in their objective function (Chinthammit).[6] If a farmer's only concern is with maximizing net returns, the optimal flexcrop strategy will erode 28 centimeters of solum in approximately 129 years. When soil quality is a concern (higher values of λ), the rate of erosion is lower. However, the major benefits of soil conservation are obtained without requiring a steep trade-off between returns and concern for soil quality because erosion time paths for $\lambda > 0.4$ are almost identical to those for $\lambda = 0.4$.

The cropping strategy that prevails in the study region is a fixed, two-year, wheat-fallow rotation. The main reason for the dominance of this rotation is that, while expected returns are lower, the variance of return is also lower. For a slope grade of 10%–24%, the fixed crop rotation erodes away 28 centimeters of solum in about 73 years compared to 129 years for the profit-maximizing flexcrop rotation and 199 years for a flexcrop rotation obtained when $\lambda = 0.6$.

The Trade-off Function

Aggregate values of each of the profit and soil quality objectives can be derived for each level of λ and plotted to give the trade-off function. The trade-off functions in figures 2 and 3 correspond to (current) solum depth levels of 20 centimeters and 10 centimeters, respectively, and average spring soil moisture (11.25 cm). For a solum depth of 20 centimeters, optimal choices change very little over the range $0 \leq \lambda \leq 0.3$, but they decline sharply thereafter, until $\lambda = 0.6$; the largest trade-offs occur in the range $0.3 \leq \lambda \leq 0.6$. For a solum depth of 10 centimeters, the comparable range is approximately $0.1 \leq \lambda \leq 0.8$. This indicates that, at 20 centimeters of solum depth, a producer must have a substantial concern with soil quality before agronomic practices are clearly distinguishable from profit-maximizing practices. At lower solum depths (fig. 3), the stewardship concern does not need to be as great in order to be able to distinguish stewardly agronomic activities.

The loss in profit when decisions based on

[5] In all of the scenarios investigated (but not reported here), conventional summerfallow was no longer a viable strategy whenever $\lambda > 0.5$.

[6] It is assumed that after 4 cm of solum depth the land will no longer be used for cropping.

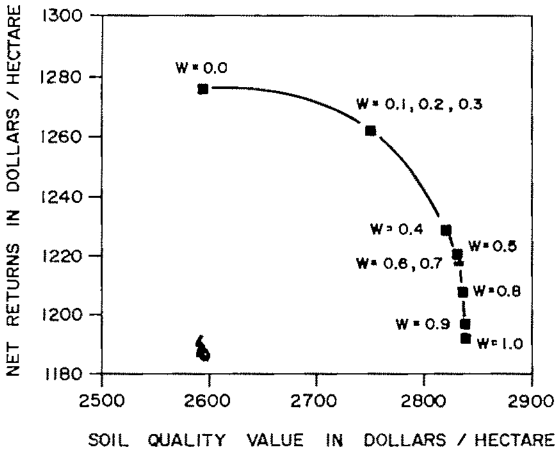

Figure 2. Trade-off function derived at solum depth = 20 centimeters and soil moisture = 11.25 centimeters

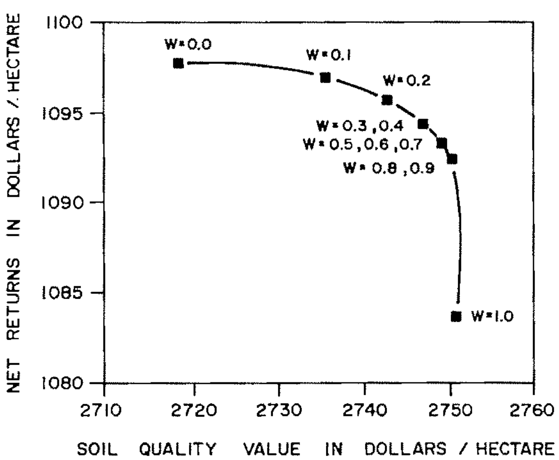

Figure 3. Trade-off function derived at solum depth = 10 centimeters and soil moisture = 1.25 centimeters

soil quality are taken can be calculated using the method described by Thampapillai and Sinden (p. 1033). The opportunity costs of the Q objective at 20 centimeters and 10 centimeters of solum, and at 11.25 centimeters soil moisture, are provided in table 5. The opportunity cost measures the sacrifice in discounted net returns required to achieve the soil quality associated with a particular level of stewardship. The opportunity costs at higher solum depth are greater than those at lower levels of solum depth. For $\lambda = 0.4$, the opportunity cost is $41.22 per hectare when solum depth is 20 centimeters. If a farmer has 10 centimeters of solum, the opportunity cost is $4.53 per hectare. When $\lambda = 0.9$, the opportunity cost in present value terms is $73.13 per hectare for the high solum depth (20 cm) and $5.69 per hectare at the lower solum depth (10 cm). The actual point on the transformation curve chosen by a producer, or the amount of profit he is willing to sacrifice, depends upon his utility function.

Conclusions

Farmers generally say that they are concerned about soil stewardship, but the results presented here indicate that it will take a substantial concern for soil quality before one observes a change in agronomic practices. Further, soil-conserving practices require sacrifices in profits that tend to be quite small, usually less than 5% of net returns. To the extent that our model is representative of actual farming practices and conditions, the results suggest that educating farmers about cropping alternatives and the low costs associated with soil conservation may yield sub-

Table 5. The Opportunity Cost of Soil Quality (Soil Moisture at 11.25 cm)

Weight (λ)	Value of Net Returns Objectives ($)	Opportunity Cost of the Soil Quality Objective ($)	Weight (λ)	Value of Net Returns Objective ($)	Opportunity Cost of the Soil Quality Objective ($)
(Solum Depth = 20 cm)			(Solum Depth = 10 cm)		
0.0	1,269.97		0.0	1,097.70	
0.1	1,263.81	6.16	0.1	1,096.89	0.81
0.2	1,263.81	6.16	0.2	1,095.62	2.08
0.3	1,263.81	6.16	0.3	1,094.29	3.41
0.4	1,228.75	41.22	0.4	1,093.17	4.53
0.5	1,220.37	49.60	0.5	1,092.32	5.38
0.6	1,218.46	51.51	0.6	1,092.26	5.44
0.7	1,217.55	52.42	0.7	1,092.20	5.50
0.8	1,207.94	62.03	0.8	1,092.01	5.69
0.9	1,196.84	73.13	0.9	1,092.01	5.69
1.0	1,192.19	77.78	1.0	1,083.58	14.12

stantial improvements in the study region's annual soil loss. Because the opportunity costs of alternative management practices are also low compared to current government transfer payments, perhaps conservation compliance can be used as a prerequisite to receiving benefits, something that is now not done in Canada.

Four areas warrant further research. (*a*) Farmers in the study region currently do not employ the flexcrop strategy which is used as the basis of our calculations. While the prevailing two-year, wheat-fallow rotation is not optimal from an expected returns point of view (Weisensel), it may be optimal for risk-averse producers. Future research should address the implications of this possibility (Young and Van Kooten). (*b*) Only one crop is considered in the model (spring wheat), and cropping and chem-fallow are the only conservation alternatives considered. The model should be expanded to take into account other crop possibilities (e.g., winter wheat, barley) and other conservation strategies (e.g., strip cropping). (*c*) Only four years of data are available. Except for yield comparisons, the extent to which the data are representative of conditions over a longer period of time is unknown. Even the yield data may not be representative of average yields in the region because the data are from experimental plots where, for example, fertilizer-use recommendations are based on information which may not be generally available on other fields. (*d*) The analysis ignores optimal farmland purchase and machinery replacement (fixed costs). Inclusion of these decision variables would improve the model's ability to represent the real world.

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Rural Road Abandonment: Policy Criteria and Empirical Analysis

Cathy A. Hamlett and C. Phillip Baumel

Deterioration and changing use patterns of the rural road system have coalesced into difficult policy decisions for local government officials. One option for consideration is abandonment of some low-volume roads. A model is developed, using utility maximization and Pareto-optimal criteria, that allows identification of policy criteria for abandonment. The criteria are empirically estimated and 4% to 12% of the roads were found to be good candidates for abandonment without a net social loss.

Key words: network simulation, road abandonment, rural infrastructure, rural roads, social decision making.

Structural shifts in rural America have dramatically changed the types of traffic on the rural road system. Increased farm size has resulted in a major reduction in the number of farms, with the surviving farmers operating on scattered farms, using larger and heavier farm equipment to travel longer distances. In addition, farmers and agribusiness firms are using larger trucks and tractor-wagon combinations to haul inputs to farms and farm output to market. At the same time, the declining farm population has resulted in fewer farm households in the rural areas. Thus, an increasing number of rural road segments no longer provide service to households (Des Moines *Register*).

On one side of the rural road problem is a system serving fewer households but also serving farmers with heavier equipment who must travel longer distances. On the other side of the problem is a system that has been deteriorating for many years. Precise data on the current condition of the local rural roads is limited because no ongoing coordinated data collection system exists, but the most recently available information indicated that 54% of the local rural roads were rated "intolerable" (U.S. Department of Agriculture). Appalachian and Delta states had the highest percentage of intolerable local rural roads (81% and 77%, respectively), while the Northern Plains and Lake States had the lowest percentage of intolerable rural roads (38% and 31%, respectively). Common complaints about local rural roads include (*a*) heavy and overweight vehicles are breaking up road surfaces, (*b*) lack of paved surfaces creates dust and rideability problems, (*c*) widths and other design characteristics are inadequate for today's large farm equipment and heavy trucks, and (*d*) narrow lanes create safety problems.

Major problems also exist with bridges on the local rural road system. Deficient bridges on local rural roads are creating serious safety and traffic constraints. A structurally deficient bridge will not carry a legal load, while a functionally obsolete bridge will carry a legal limit but is too narrow or has other characteristics that do not meet minimum design standards. Nationally, 166,783 bridges, or 55% of all the inventoried off-federal-aid bridges, were deficient (U.S. Department of Transportation 1987). Even this number understates the magnitude of the problem because bridges under 20 feet long were not included in the inventory. Thousands of bridge structures under 20 feet need replacement or rehabilitation (Smith).

The distribution of deficient bridges among states indicates that the off-system bridge problem is national in scope. The states with the highest percentage of deficient bridges are Kentucky, North Carolina, Missouri, Nebraska, South Dakota, Louisiana, New York, and West Virginia. The states with the largest number of deficient bridges are Texas, Iowa, Kansas, Missouri, North Carolina, and Oklahoma. States in the Northeast, Midwest, Southeast, and Southwest are included in the group with a high per-

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centage or a high total number of deficient bridges (U.S. Department of Transportation 1987).

The estimated replacement costs for modernization of the rural system are staggering. An Iowa study projected that county-road revenue buying power would cover only 51% of the needs for 1982–2001 period (Iowa Department of Transportation 1983). Yet, public funding increases for rural infrastructure have perennially lagged behind these burgeoning maintenance and reconstruction needs. Local officials face the dilemma of their governments being held legally liable for the condition of the structures without adequate funding to meet reasonable design standards (Chicoine and Walzer 1986). A likely solution to the dilemma will be a reduction in the road system, probably through a combination of several alternatives. One alternative is abandoning low-traffic roads with no property accesses (Baumel, Schornhorst, and Smith). Previous research on benefit/cost estimation relative to rural roads has suggested tentatively that some benefits are gained from rural road abandonment. Several studies, including ones by Hartwig and the Iowa Department of Transportation (1982) have suggested that abandoning roads may lead to cost savings greater than benefits foregone.

Only a small number of studies have attempted to collect data and empirically address the issue of reducing the rural road system. In Pennsylvania, the Department of Transportation identified an Agricultural Access Network, where roads judged to be most important to the rural areas for agricultural product transportation were identified. The nonfarm rural resident, however, was not included in the study.

A circuity-type model was used by Nyamaah and Hitzhusen to estimate the rerouting costs of posting or closing fifteen rural bridges in Ohio. The model showed substantial benefits for selected bridge repair or replacement. Unfortunately, all types of rural traffic, such as farm equipment travel, were not quantified and rerouted after the bridge closing.

Johnson published a theoretical model for estimating the benefits of road improvements. His analysis was conceptual and did not estimate any benefits. The major factors for an accurate benefit measurement are identified in the model as traffic origins/destinations, volumes of traffic, and composition of vehicles. More recently, Shaffer has called for an extensive benefit/cost evaluation of the rural road system. Because rural road abandonment is an important reduction strategy, and because the political implications for local officials are considerable, the following analysis focuses upon road abandonment as a policy option. Closing a road is an unpopular policy option, and a need exists for an objective criteria and analysis to support the decision making.

The model that follows allows analysis of road abandonment policy by identifying theoretical criteria to determine when a road should be abandoned. A method for empirically estimating the criteria is also outlined and the estimation results are reported. Specifically, the objectives of this work are to (*a*) model individual preferences for the road system, (*b*) develop a societal model for road system decisions, (*c*) derive policy decision criteria, and (*d*) empirically estimate the decision criteria.

The Model

The rural road system is a public good, mostly because a person driving on a rural road (or consuming a unit of a public good) does not preclude others from driving on the same road (or consuming the same good) (Samuelson 1954, 1955). Another way to think of the private/public good distinction is that a unit of a private good enters only one person's utility function. A unit of public good enters multiple utility functions. This multiplicity has also been called a joint distribution constraint because supplying a public good to one is not possible without supplying it to others (Musgrave and Musgrave or Cornes and Sandler). Any model of the road system must incorporate this public good aspect.

A utility framework is used to model person j's demand for Q, the rural road system. The individual's utility function, assumed to be strictly increasing in all arguments, smooth, quasi-concave, and twice-continuously differentiable, is represented by

$$(1) \qquad U^j(y^j, x^j), j = 1, \ldots, h,$$

where y^j is a private good or some bundle of private goods, and x^j represents the benefits derived from the road system. A total of h individuals have a demand for the road system being studied.

The translation from the benefit space of x^j to the road system space, Q, is assumed to be strictly increasing, smooth and quasi-concave:

$$(2) \qquad x^j = f^j(Q), j = 1, \ldots, h.$$

Each rural traveler has a function, f^j, that translates the road system, Q, into benefits from the system, and these benefits enter into the individual's utility function as x^j.

The rural road system, Q, is an $n \times 1$ vector of indexes representing all the n roads in the rural system. The distance and quality of the n roads are each represented by an index, q^i, where $i = 1, \ldots, n$. If q^i is one mile of gravel-surfaced road, it could be compared to q^j, one mile of road with a dirt surface. In this case q^i is greater than q^j.

Income considerations constrain the maximization of utility, with the constraint having the following form:

$$(3) \qquad M^j = y^j + t^j(p'Q), j = 1, \ldots, h.$$

Income is spent on the private good, y^j (taken to be the *numeraire,* so $p^y = 1$), and taxes to support Q. The tax system is simple; person j pays t^j, $0 < t^j < 1$, which is proportion of $p'Q$—the cost of the public road system. The value $p'Q$ assumes that an $n \times 1$ vector, p, of road costs is known. The sum of $t^j(p'Q)$ over all h people equals the provision cost for the rural public road system.

A small part of all decisions made by individual j is being explicitly modeled. A separability between the modeled decisions on road provision and those made in other parts of individual j's life is being implicitly assumed, an assumption often used when the modeled good requires only a small proportion of an individual's income and time to consume (Kealy and Bishop). In the income constraint, only the taxes paid for the road system are included, which is an abstraction, though not as extreme as one might think. While a rural resident may not know the exact amount of his or her tax dollars going to support the road system, a perception of the general proportion, however, can be formed by the person.

The next step for policy analysis is to identify the public's preferences for the rural road system. Pareto-optimal criteria are used at the societal decision rule to search for a socially optimal equilibrium, where no one can be made better off without someone experiencing a decline in utility.

For notational clarity, the Pareto model is set up to maximize person 1's utility subject to everyone else obtaining at least a given utility level, U^{oj} where $j = 2, \ldots, h$, and also subject to an aggregate income/consumption transformation function. The h people using the rural road system are arbitrarily numbered from 1 to h. The maximization problem is

$$(4) \qquad \max_{(Y,Q)} U^1(y^1, f^1(Q)),$$

subject to

$$\sum_{j=1}^{h} M^j \geq \sum_{j=1}^{h} (y^j + t^j(p'Q)),$$

$$U^j(y^j, f^j(Q)) \geq U^{oj} j = 2, \ldots, h$$

$$Y \geq 0, Q \geq 0.$$

In (4), Y is an $h \times 1$ vector containing y^1, y^2, $\ldots$, y^h. A linear resource transformation function is assumed, implying constant costs, where the sum over all M^j represents exogenously fixed resources. The Lagrangian form for (4) is

$$L = U^1(\cdot) + \lambda \left\{ \sum_{j=1}^{h} (M^j - y^j) - p'Q \right\} + \sum_{j=2}^{h} \gamma^j [U^j(\cdot) - U^{oj}].$$

The relevant Kuhn-Tucker conditions are as follows:

$$(5) \qquad \gamma^j U_y^j \leq \lambda, y^j \geq 0, y^j \frac{\partial L}{\partial y^j} = 0, \quad j = 1, \ldots, h; \gamma^1 = 1;$$

$$(6) \qquad \sum_{j=1}^{h} \gamma^j U_x^j f_{qi}^j \leq \lambda p^i, q^i \geq 0, q^i \frac{\partial L}{\partial q^i} = 0, \quad i = 1, \ldots, n; \gamma^1 = 1.$$

Note that U_y^j represents $\partial U^j / \partial y^j$ and so forth. Also the sum of t^j over all h people equals one, so t^j drops out of the Lagrangian. Dividing (5) into (6) yields the following:

$$(7) \qquad \sum_{j=1}^{h} f_{qi}^j MRS_{xy}^j \leq p^i, i = 1, \ldots, n,$$

where MRS_{xy} is the ratio of the partial derivative of U^j with respect to x and the partial derivative of U^j with respect to y. Relationship (7) says that the societal rule for a quality/provision decision on road i involves a trade-off between the cost of providing the road (p^i) and the weighted sum of the marginal rates of substitution between the private and public goods for all people.

Consider an abandonment decision relative to road i. To simplify further discussion, the left side of (7) is referred to as b. If b is less than

p^i, then the benefits society gains from the road are less than the cost of providing the road. In this case, road q^i should be abandoned ($q^i = 0$). If b is greater than p^i, then the road should remain in the public system.

For the above decision rule to be useful, a method for estimating the benefits and costs of a road is needed. The next section outlines the methodology for such estimation and the following section reports results from the estimation.

Outline of Empirical Estimation

Equation (7) suggests a comparison of benefits and costs. An estimation technique is needed to capture the marginal benefit accruing to society from a road as well as the cost of providing that road.

Road Benefit Estimation

The sum of everyone's weighted marginal rate of substitution between the road system and the private good must be empirically estimated before policy comparisons can be made. Estimation must capture the value of a marginal change in road system benefits in terms of the private good, y. Measuring an individual's marginal rate of substitution is impossible, but a proxy can be used.

A proxy that has intuitive appeal and empirical possibilities is the change in travel cost incurred by rural travelers as the road system varies. As the road system is reduced through road abandonment, the rural traveler may have to change routes to avoid the abandoned road, and this can be translated into a cost. For convenience, denote the change in travel cost as ΔTC; ΔTC is thus a reasonable proxy for the marginal value a person puts on a road.

Because physically closing a road and measuring the cost to those who have to go around the road would be difficult and costly, a simulation model was used to estimate ΔTC. Traffic flows were simulated, allowing an estimation of travel-cost changes as changes to the road system were made. The rural road system for a given area was represented as a network, and Dijkstra's algorithm was used to find minimum cost routes for the rural travelers (Pautsch, Hamlett, and Baumel).

Dijkstra's algorithm develops the shortest tree by fanning out from an origin node. The advantage of this procedure is that once an arc is part of the tree, it never leaves. Therefore, the shortest route to all nodes within the tree is known. See Mandl or Dreyfus and Law for further discussion.

The policy of road abandonment was then investigated by changing the network (i.e., to abandon a road, remove an arc from the network) and then the simulation model was used to reroute the traffic. Minimum cost routing of each trip was found through the simulation model, and then the cost of traveling on the status quo road system was summed. After altering the network to reflect an abandonment alternative, the traffic was rerouted and the new cost tabulated. The difference in the travel cost of the two solutions is ΔTC, an estimate at the margin of the road system benefits.

The use of this type of proxy assumes that the number, origin, and destination of the traveler's trips remains the same after the policy implementation. Some trip consolidation would probably occur after the road system was reduced and the proxy does not account for such consolidation. A more detailed discussion of the traffic simulation model is presented in Baumel et al. The data needed for the simulation were the origin, destination, frequency, and vehicle used on each trip over a period of time.

Road Cost Estimation

The costs of road provision are represented by p in equation (7), where p is the vector of prices to provide the various index values of road types. For the simulation, road costs per mile and per vehicle-pass for different road-surface types were needed. The cost of providing a specific road is dependent on the structure of the entire road system. Because the price of road maintenance and reconstruction costs are dependent on the number and types of vehicles that travel over the road, investigating the abandonment of the road i must include the additional traffic inherited by adjacent roads when road i is abandoned.

Information from the simulation model was used to estimate the road-provision price. The first run of the simulation model, before the road system was changed, gave estimates of daily traffic on all roads. After a system change, when the traffic was rerouted, daily traffic estimates were also obtained. By calculating the total cost of road provision before and after a policy was implemented, the price of providing road i was estimated. The computer algorithm used to es-

timate the road provision cost is presented in Baumel et al.

Empirical Estimation

For the empirical estimation, three study areas were chosen. All were in Iowa but represented very different rural situations. Each area was 100 square miles. One area, located in Hamilton County, has a high agricultural tax base, a high percentage of paved roads, and relatively few bridges. The second area, located in Shelby County, has a relatively low agricultural tax base, hilly terrain, a low percentage of paved roads, a large number of oil-coated and earth-surface roads, and many bridges. The third area, located in Linn County, has a high agricultural tax base, a high percentage of paved roads, and a large number of nonfarm households commuting to nearby cities.

Primary data were collected on trip origin, destination, frequency, and vehicle used for rural residents in three areas. Data for 1982 on personal and farm-related travel were obtained by personal interviews from a census of households and farms in the three study areas. Farmers whose residences were outside the study area but who farmed land within the area were also contacted for personal interviews.

The questionnaire obtained data on the exact location of each respondent's home, land tracts within and outside the study areas, and the location of all home and field driveways. In addition, the number of yearly trips by vehicle type was obtained for each farm and household. A more detailed description of the primary data collection is in Hamlett, Pautsch, and Baumel.

Cost functions were developed for the numerous vehicles used by the rural residents. A cost per mile value for different surface types was developed for all vehicles (Hanson, Hamlett, and Baumel).

Many origins or destinations of the trips were outside the original 10-mile by 10-mile study area. To incorporate out-of-study area origins or destinations, the network was expanded to include a three-mile border around each study area. The expansion allowed direct routing for many of the out-of-study area trips. Also, border nodes were used for each side of the study area. Some trips were then assigned an origin or destination of the border node, which allowed routing the trip along the least-cost route to one edge of the study area. The goal was to simulate the trip through the study area, not the whole trip.

Prices or costs of providing the road system were constructed by collecting data on maintenance and resurfacing costs of roads and bridges in the three study areas. Provision costs of the road systems included road maintenance, road reconstruction, road resurfacing, bridge maintenance, and bridge reconstruction. Because some of these costs, such as reconstruction costs, occur infrequently, they were annualized and converted to net present values.

Also included in the price of providing a road was the productive value of the underlying land. A local cash rent value was used as a proxy of the land's productivity in the absence of the road.

Policy Evaluation

Once the data had been gathered and compiled and the road system incorporated into the network model, the policy of rural road abandonment could be evaluated.

The simulation model was used to estimate equation (7) for six sets of road abandonments. As was described before, the traveler's trips were routed over the status quo network and the travel costs summed along with road provision costs. For evaluation of an abandonment policy, each road in the set to be abandoned was removed from the network, travelers then were routed over the altered network, and again costs were summed. The difference in costs between the two states provided an estimate for equation (7). Decisions on roads to include in the abandonment set were made in conjunction with the county engineers who had responsibility for the roads in the study areas. Sets of roads, rather than single roads, were investigated because of the expense of each model estimation. The to-be-abandoned roads did not deny access to any residence or field.

Table 1 contains the estimation results for the six sets of abandonments. The relationship between benefits and costs differed for each policy alternative. For the first set of roads abandoned in each study area, the price of providing the roads was greater than the total individual and public benefits gained from having the roads in the system. Thus, the decision criteria indicated that these sets of roads should be abandoned. In the Linn and Shelby County areas, additional sets of roads were abandoned and the benefits/costs estimated. These three additional abandonments resulted in the benefits being greater than the costs, indicating that abandonment is not optimal.

Table 1. Decision Criteria Estimation for Rural Road Abandonment

Policy Alternatives	Benefits (b) from Roads Remaining in System	Costs Saved (p^i) from Abandonment	Difference (Benefit-Cost)
	($)		
Linn County study area[a]			
L_1	29,014	29,382	−368
L_2	28,138	19,534	8,604
Shelby County study area[b]			
S_1	39,276	52,030	−12,754
S_2	78,436	33,089	45,347
S_3	77,052	16,123	60,929
Hamilton County study area[c]			
H_1	68,521	85,002	−16,481

[a] For policy L_1, 5.25 miles of road were abandoned, and an additional 3.75 miles were abandoned in L_2 (5.25 miles is approximately 4% of the unpaved roads in the study area).
[b] For policy S_1, 9.25 miles were abandoned, an additional 6.75 miles in S_2, and an additional 5.25 miles in S_3 (9.25 miles is approximately 5% of the unpaved roads in the study area).
[c] 17.75 miles of road were abandoned (slightly over 12% of the unpaved roads in study area).

The net savings from abandonment varied by study area. Substantial maintenance and reconstruction costs were saved by the local governments because of the reduction in road system. Because the net savings were positive for the first abandonment solution in each area, it is clear that some roads are good abandonment candidates. But a high percentage of the roads could not be abandoned without a net loss to society. On a per mile–per year basis, the net savings ranged from $70 for the first 5.25 miles abandoned in Linn to $1,379 for the first 9.25 miles abandoned in Shelby County. Abandoning 17.75 miles of low-volume, no-access roads in Hamilton resulted in a net benefit of $16,481, or $929 per mile abandoned. The net savings from abandonment were relatively low because the trips that would normally travel over the abandoned roads were rerouted, resulting in an increased travel cost.

Comparisons of the estimations for L_2, S_2, and S_3 to L_1, S_1, and H_1 show that as more roads are abandoned, the costs to travelers increase much faster than the savings in road-provision costs. Most of the S_2 roads had between ten and thirty average vehicles per day, and the L_2 and S_3 roads generally had more than thirty vehicles per day.

Conclusions

A utility-maximization model provided a criterion for deciding whether a road should be abandoned or left in the public system. The criterion involves comparing the sum of weighted individual marginal rates of substitution between road benefits and private goods to the price of providing a road. If total benefits of a road are less than the cost of providing that road, the optimal policy decision is to remove the road. Benefits that are larger than the costs indicate a road that should remain in the public system.

A procedure for estimating the benefits and costs was outlined. The benefit estimation involves collecting travel information from the rural residents and using a simulation model for routing trips. The empirical estimation involved a large primary data collection effort and focused upon three midwestern study areas. Benefit and cost estimation was done for six abandonment alternatives. Three of the six sets of roads evaluated for abandonment were identified as good candidates for abandonment. The estimation indicated that between 4% and 12% of the roads in the areas studied could be abandoned with a net gain to society. Thus, only a relatively small number of miles of abandoned low volume rural roads would produce greater cost savings to local governments than additional costs to the traveling public.

Local government officials, however, may be reluctant to make even small reductions in the local rural road system because of political concerns along with legal costs and court-awarded damages. Thus, there is a need for legislation to reduce the political and financial liability from abandonment. Legislative changes could include denying claims to an individual if the road proposed for abandonment is a second access, placing an upper limit on damage claims, permitting local governments to withdraw or revise a proposed abandonment if a court appeal may

result in an excessive damage award, or authorizing the appointment of committees to develop and implement abandonment proposals to relieve elected officials of the political liability.

The small amount of economically sound road abandonment, however, is not likely to solve completely the local government financial problem of providing rural road access. Other alternatives to road abandonment that should be evaluated for potential net cost savings include lowering maintenance on roads that serve only access to farm fields, converting dead-end and other low-volume roads to private drives, and closing rather than reconstructing some bridges on low-volume rural roads. The theoretical model could be expanded to allow development of other policy criteria (Hamlett). Criteria for returning roads to private ownership and reducing the maintenance levels on some roads could be easily developed from the model. The return-to-private-ownership option would involve separating term b into the benefits associated with the individuals who would own the road and those benefits accruing to the rest of society. If society benefits are low but the individual benefits are high, the road would be a likely candidate for removal from the public system. The other policy alternative, reducing maintenance levels would have the effect of lowering p while also increasing travel cost.

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Using the Wrong Discount Rate to Allocate an Exhaustible Resource

John Rowse

What are the social welfare implications of using the wrong discount rate to allocate an exhaustible resource? Utilizing a simple numerical model, it is found that, over the (real) discount rate range of 6% to 9%, the welfare losses of employing a rate no more than 3% different from the social rate are small and decline as the social rate rises, even for stringent supply circumstances. However, substantial transfers of surplus between producers and consumers occur as the improper rate deviates from the social rate. Other issues such as income distribution immediately loom larger when a discount rate is chosen.

Key words: control theory, discount rate choice, exhaustible resources.

The discount rate has long been recognized as critical for determining the efficient allocation of an exhaustible resource. Heretofore, however, the social welfare losses from using an improper rate have not been measured. In this paper the social welfare losses are quantified using a simple numerical model with two different sets of parameters. The model (Chapman) features a time-invariant linear demand function, constant marginal production costs, a known exogenous stock, an endogenous exhaustion date, and endogenous prices and allocations. The model is set forth in the next section, and the basic formulas are derived; then, the base case and sensitivity results are presented and interpreted. Concluding remarks are provided in the final section.

The Model

The demand function is linear and stationary and its inverse or willingness-to-pay (WTP) function is specified by $p(y) = \beta_2 - \beta_1 y$, where y is the consumption rate, p the price, and β_1 and $\beta_2 > 0$. The known resource stock is S, and the marginal cost of production α is constant for all units. The social net surplus on consumption of unit y is $p(y) - \alpha$, and hence the aggregate net surplus ns on consumption of y units is

$$(1) \qquad ns(y) = \int_0^y (p(x) - \alpha)\,dx = \beta_2 y - \beta_1 y^2/2 - \alpha y.$$

Discounting at rate r, the present value at time 0 of social welfare through time t is

$$(2) \qquad SW^r(t) = \int_0^t ns(y)\,e^{-rs}\,ds.$$

Superscript r emphasizes the dependence of SW on the discount rate. With slight notational changes from the original formulation, Chapman's problem is to find the consumption path $y_c(t)$ and exhaustion year T_r to:[1]

$$(3) \qquad \left[\begin{array}{l} \text{Maximize } SW^r(T) = \displaystyle\int_0^T \left\{\int_0^{y(t)} [p(y) - \alpha]\,dy\right\} e^{-rt}\,dt, \text{ subject to} \\ p(y) = \beta_2 - \beta_1 y;\ y(t) = \dfrac{dX(t)}{dt};\ \displaystyle\int_0^T y(t)\,dt = X(T) \le S; \\ p, y \ge 0; \text{ and } py - \alpha y \ge 0. \end{array}\right.$$

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[1] A similar framework has been employed by others. For example, this same model with $\beta_1 = 1$ is used by Gordon.

If the demand extinction price β_2 exceeds the marginal cost α—an assumption adopted here, then the stock S will be completely exhausted.

The optimal solution consists of several elements. The efficient depletion (competitive-market) path is

$$(4) \quad y_c^r(t) = \beta_3 - \beta_3 e^{r(t-T_r)} \quad 0 \le t \le T_r,$$

where $\beta_3 = (\beta_2 - \alpha)/\beta_1$, and the equation determining T_r is

$$(5) \quad T_r + e^{-rT_r}/r = S/\beta_3 + 1/r.$$

An analytical solution for T_r is not possible; but, given S, β_3, and r, this equation has a single root for T_r, which can readily be found by Newton's method. Substituting $y_c^r(t)$ into the WTP function and simplifying yields the efficient price trajectory:

$$(6) \quad p_c^r(t) = \alpha + (\beta_2 - \alpha)\, e^{r(t-T_r)} \quad 0 \le t \le T_r.$$

At time t the efficient price consists of the marginal cost plus a user cost (Dasgupta and Heal, chap. 6). Hence the second term on the right-hand side of (6) specifies user cost as a function of time.

Substituting $y_c^r(t)$ into (1), then substituting $ns(y)$ into (2), integrating from 0 to T_r and simplifying yields maximum social welfare:

$$(7) \quad SW_c^r(T_r) = \beta_1\beta_3^2(1 - e^{-rT_r})^2/2r.$$

Unit producer surplus is the difference between price and marginal cost. Thus the producer surplus associated with consuming y units is

$$(8) \quad ps(y) = [p(y) - \alpha]\, y = \beta_2 y - \beta_1 y^2 - \alpha y.$$

Discounting at rate r, the present value at time 0 of aggregate producer surplus through time t is

$$(9) \quad PS^r(t) = \int_0^t ps(y)\, e^{-rs}\, ds.$$

Substituting $y_c^r(t)$ from (4) into (8), then substituting $ps(y)$ from (8) into (9), integrating from 0 to T_r and simplifying yields the producer surplus associated with the efficient depletion path:

$$(10) \quad PS_c^r(T_r) = \beta_1\beta_3^2\,[e^{-rT_r}(rT_r - 1) + e^{-2rT_r}]/r.$$

Finally, consumer surplus is

$$(11) \quad CS_c^r(T_r) = SW_c^r(T_r) - PS_c^r(T_r).$$

Using the Wrong Discount Rate

What happens when the discount rate changes? Clearly from (5), when r changes, T_r changes. It is easily shown that

$$(12) \quad dT_r/dr = -[e^{rT_r} - (1 + rT_r)]/[r^2(e^{rT_r} - 1)].$$

Therefore $dT_r/dr < 0$ and a higher discount rate speeds exhaustion. Furthermore, because $d(rT_r)/dr = Se^{rT_r}/[\beta_3(e^{rT_r} - 1)] > 0$ from (5), near-term user costs in (6) shrink with r, and thus near-term consumption rates increase with r (Hartwick and Olewiler, p. 68). However, if the marginal cost varies either with the discount rate or with the production rate, then these inferences are not possible (Gordon, Watkins, Farzin).

If the allocation problem is solved using discount rate $w \ne r$, then substituting w for r in (4) yields the optimal consumption trajectory:

$$(13) \quad y_c^w(t) = \beta_3 - \beta_3 e^{w(t-T_w)} \quad 0 \le t \le T_w,$$

and T_w can be found by substituting w for r in (5) and solving for T_w. How does this trajectory perform relative to $y_c^r(t)$? Substituting $y_c^w(t)$ into (1), $ns(y)$ from (1) into (2), discounting at rate r, integrating from 0 to T_w, and simplifying yields

$$(14) \quad SW_c^{w:r}(T_w) = \begin{bmatrix} \mu[1 - e^{-rT_w}(1 + rT_w)]/r, & w = r/2 \\ \mu[1 - e^{-rT_w}]/r + \mu e^{-2wT_w}[1 - e^{(2w-r)T_w}]/(2w - r), & w \ne r/2 \end{bmatrix},$$

where $\mu = (\beta_2 - \alpha)^2/(2\beta_1)$. The notation $w{:}r$ indicates that rate $w \ne r$ is used when the correct rate is r. Moreover, substituting $y_c^w(t)$ into (8), $ps(y)$ from (8) into (9), discounting at rate r, integrating from 0 to T_w, and simplifying yields the corresponding producer surplus:

$$(15) \quad PS_c^{w:r}(T_w) = \begin{bmatrix} -2\mu e^{-2wT_w}(1/w + T_w) + 2\mu e^{-wT_w}/w, & w = r/2 \\ 2\mu e^{-wT_w}[e^{(w-r)T_w} - 1]/(w - r) - 2\mu e^{-2wT_w}[e^{2w-r} - 1]/(2w - r), & w \ne r/2 \end{bmatrix}.$$

Finally, consumer surplus associated with $y_c^w(t)$ is

$$(16) \quad CS_c^{w:r}(T_w) = SW_c^{w:r}(T_w) - PS_c^{w:r}(T_w).$$

Because $y_c^r(t)$ is the unique maximizer for (3), $SW_c^{w:r}(T_w) < SW_c^r(T_r)$ for all $w \neq r$. But how far $SW_c^{w:r}(T_w)$ is below the maximum social welfare must be answered numerically for particular values of the model parameters. The approach is as follows. First, given r, solve (5) for T_r, then evaluate $SW_c^r(T_r)$ using (7). Second, given $w \neq r$, substitute w for r in (5) and solve for T_w, then evaluate $SW_c^{w:r}(T_w)$ using (14). Compare this level of social welfare with the maximum social welfare. Complete this second step for several different values of w. Finally, because the social discount rate is not known, repeat both steps for different values of r as well.

Base Case Results

Chapman's parameter values have been adopted for the base case.[2] The demand extinction price of \$75 per barrel can be viewed as the cost of backstop supplies 3.75 times the cost of depletable crude, and demand can also be viewed as shifting completely to these supplies when crude oil is exhausted. Moreover, the stock will support 54.05 years of consumption at a price equal to marginal cost; hence, the stock is relatively large, and exhaustion is not an immediate concern.

Table 1 specifies the character of the efficient depletion paths for discount rates ranging from 3% to 12%. This range of r likely includes the social discount rate and captures both the 5% and 10% rates used in some exhaustible resource models (Daniel and Goldberg, Manne). At a 3% discount rate, the stock lasts 84.76 years and the initial price and consumption rate are, respectively, \$24.33 per barrel and 20.27 billion barrels per year. Consumption at this rate is sustained for nearly a decade, declines slowly, then falls more rapidly. By contrast, for the 12% discount rate, the stock lasts 62.37 years, the initial price is \$20.03 per barrel (17.67% below that of the 3% rate), and the initial consumption rate is 21.99 billion barrels per year (8.49% above that of the 3% rate). Consumption is sustained at this rate for nearly four decades, then declines rapidly. For the 12% rate, user costs are very small for $t = 0$ because the initial price is close to marginal cost.

Several observations are immediate. First, because of the relatively large stock size, the differences between the 3% and 12% solutions, while not small, are not vast for the first three decades. This outcome confirms that the depletion problem is not a pressing one for Chapman's parameter values. Second, the major changes in depletion paths occur when a low discount rate is increased by one percentage point rather than when a high discount rate is increased by this amount. This is partly because a one-percentage-point rise in the discount rate is proportionately greater at a low discount rate than at a high discount rate.[3] Third, the consumption paths for discount rates in the range of 9% to 12% are remarkably similar.[4] Consequently, if the social discount rate lies in this range, but a rate different from the social rate is used which still lies in this range, then effi-

[2] With y measured in billion barrels/year, his specific parameter values were: $\beta_1 = 2.5$ (\$/barrel per billion barrels/year), $\beta_2 = 75.0$ (\$/barrel), $\alpha = 20.0$ (\$/barrel) and $S = 1189.0$ (billion barrels). Because β_2 exceeds α, complete exhaustion is assured.

[3] This cannot be the sole reason. For example, raising the discount rate from 3% to 4% (a 33% increase) cuts the stock life by 6.82 years (or 8.05%), while raising the discount rate from 9% to 12% (also a 33% increase) cuts the stock life by 2.75 years (or 4.22%), a more muted response.

[4] Consumption paths for rates exceeding 12% are very similar to the 12% path. Hence, little is lost by excluding from consideration paths for rates exceeding 12%.

Table 1. Character of the Optimal Consumption Trajectories for the Base Case

Discount Rate	Exhaustion Year	Initial Price (\$/Barrel)	Efficient Consumption Rate (10^9 Barrels/Year) at Year 0	10	20	30	40	50	60	70	80
0.03	84.76	24.33	20.27	19.66	18.85	17.74	16.25	14.25	11.53	7.87	2.93
0.04	77.94	22.43	21.03	20.55	19.83	18.77	17.18	14.80	11.27	5.99	0.00
0.05	73.54	21.39	21.44	21.08	20.49	19.51	17.89	15.22	10.82	3.57	0.00
0.06	70.47	20.80	21.68	21.42	20.94	20.06	18.46	15.56	10.26	0.61	0.00
0.07	68.21	20.46	21.81	21.63	21.25	20.48	18.95	15.85	9.62	0.00	0.00
0.08	66.48	20.27	21.89	21.76	21.47	20.81	19.36	16.12	8.90	0.00	0.00
0.09	65.12	20.16	21.94	21.85	21.62	21.07	19.71	16.36	8.13	0.00	0.00
0.10	64.03	20.09	21.96	21.90	21.73	21.27	20.01	16.59	7.30	0.00	0.00
0.11	63.13	20.05	21.98	21.94	21.81	21.42	20.27	16.81	6.40	0.00	0.00
0.12	62.37	20.03	21.99	21.96	21.86	21.55	20.50	17.02	5.45	0.00	0.00

Table 2. Performance Measures for the Base Case Analysis

SW: Social Welfare CS: Consumer Surplus PS: Producer Surplus

Social Discount Rate	Consumption Trajectory Optimal for Discount Rate Specified: 0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12
0.03	SW = 17.119 (0.00E + 0) CS = 11.976 (0.00E + 0) PS = 5.144 (0.00E + 0)	SW = 17.076 (−2.49E − 1) CS = 13.044 (8.92E + 0) PS = 4.033 (−2.16E + 1)	SW = 17.000 (−6.97E − 1) CS = 13.760 (1.49E + 1) PS = 3.239 (−3.70E + 1)	SW = 16.921 (−1.15E + 0) CS = 14.260 (1.91E + 1) PS = 2.662 (−4.83E + 1)	SW = 16.851 (−1.57E + 0) CS = 14.618 (2.21E + 1) PS = 2.233 (−5.66E + 1)	SW = 16.789 (−1.93E + 0) CS = 14.881 (2.43E + 1) PS = 1.908 (−6.29E + 1)	SW = 16.737 (−2.23E + 0) CS = 15.079 (2.59E + 1) PS = 1.658 (−6.78E + 1)	SW = 16.691 (−2.50E + 0) CS = 15.231 (2.72E + 1) PS = 1.461 (−7.16E + 1)	SW = 16.652 (−2.73E + 0) CS = 15.349 (2.82E + 1) PS = 1.303 (−7.47E + 1)	SW = 16.619 (−2.92E + 0) CS = 15.444 (2.90E + 1) PS = 1.175 (−7.72E + 1)
0.04	SW = 13.783 (−2.36E − 1) CS = 10.008 (−8.36E + 0) PS = 3.775 (3.04E + 1)	SW = 13.816 (0.00E + 0) CS = 10.921 (0.00E + 0) PS = 2.895 (0.00E + 0)	SW = 13.801 (−1.06E − 1) CS = 11.527 (5.55E + 0) PS = 2.274 (−2.14E + 1)	SW = 13.773 (−3.11E − 1) CS = 11.944 (9.36E + 0) PS = 1.829 (−3.68E + 1)	SW = 13.742 (−5.31E − 1) CS = 12.238 (1.21E + 1) PS = 1.505 (−4.80E + 1)	SW = 13.714 (−7.38E − 1) CS = 12.450 (1.40E + 1) PS = 1.264 (−5.63E + 1)	SW = 13.688 (−9.25E − 1) CS = 12.607 (1.54E + 1) PS = 1.081 (−6.27E + 1)	SW = 13.665 (−1.09E + 0) CS = 12.725 (1.65E + 1) PS = 0.940 (−6.75E + 1)	SW = 13.645 (−1.23E + 0) CS = 12.816 (1.74E + 1) PS = 0.829 (−7.14E + 1)	SW = 13.628 (−1.36E + 0) CS = 12.887 (1.80E + 1) PS = 0.740 (−7.44E + 1)
0.05	SW = 11.426 (−6.04E + 1) CS = 8.540 (−1.32E + 1) PS = 2.886 (7.45E + 1)	SW = 11.484 (−9.68E − 2) CS = 9.325 (−5.24E + 0) PS = 2.159 (3.05E + 1)	SW = 11.495 (0.00E + 0) CS = 9.841 (0.00E + 0) PS = 1.654 (0.00E + 0)	SW = 11.490 (−4.80E − 2) CS = 10.191 (3.56E + 0) PS = 1.299 (−2.15E + 1)	SW = 11.479 (−1.44E − 1) CS = 10.435 (6.03E + 0) PS = 1.044 (−3.69E + 1)	SW = 11.467 (−2.52E − 1) CS = 10.608 (7.79E + 0) PS = 0.859 (−4.81E + 1)	SW = 11.454 (−3.57E − 1) CS = 10.734 (9.07E + 0) PS = 0.721 (−5.64E + 1)	SW = 11.443 (−4.54E − 1) CS = 10.827 (1.00E + 1) PS = 0.617 (−6.27E + 1)	SW = 11.433 (−5.41E − 1) CS = 10.897 (1.07E + 1) PS = 0.536 (−6.76E + 1)	SW = 11.424 (−6.20E − 1) CS = 10.951 (1.13E + 1) PS = 0.473 (−7.14E + 1)
0.06	SW = 9.704 (−8.96E − 1) CS = 7.415 (−1.61E + 1) PS = 2.288 (1.40E + 2)	SW = 9.767 (−2.50E − 1) CS = 8.097 (−8.38E + 0) PS = 1.670 (7.51E + 1)	SW = 9.787 (−4.22E − 2) CS = 8.541 (−3.36E + 0) PS = 1.246 (3.07E + 1)	SW = 9.791 (0.00E + 0) CS = 8.838 (0.00E + 0) PS = 0.953 (0.00E + 0)	SW = 9.789 (−2.23E − 2) CS = 9.042 (2.31E + 0) PS = 0.747 (−2.16E + 1)	SW = 9.785 (−6.87E − 2) CS = 9.185 (3.92E + 0) PS = 0.600 (−3.71E + 1)	SW = 9.780 (−1.22E − 1) CS = 9.287 (5.07E + 0) PS = 0.493 (−4.83E + 1)	SW = 9.774 (−1.76E − 1) CS = 9.361 (5.91E + 0) PS = 0.414 (−5.66E + 1)	SW = 9.769 (−2.26E − 1) CS = 9.416 (6.54E + 0) PS = 0.353 (−6.29E + 1)	SW = 9.765 (−2.73E − 1) CS = 9.457 (7.01E + 0) PS = 0.307 (−6.78E + 1)
0.07	SW = 8.406 (−1.08E + 0) CS = 6.535 (−1.78E + 1) PS = 1.871 (2.39E + 2)	SW = 8.466 (−3.71E − 1) CS = 7.133 (−1.02E + 1) PS = 1.333 (1.42E + 2)	SW = 8.488 (−1.09E − 1) CS = 7.518 (−5.38E + 0) PS = 0.970 (7.58E + 1)	SW = 8.496 (−1.91E − 2) CS = 7.773 (−2.17E + 0) PS = 0.723 (3.10E + 1)	SW = 8.498 (0.00E + 0) CS = 7.946 (0.00E + 0) PS = 0.552 (0.00E + 0)	SW = 8.497 (−1.06E − 2) CS = 8.065 (1.50E + 0) PS = 0.432 (−2.17E + 1)	SW = 8.495 (−3.32E − 2) CS = 8.148 (2.55E + 0) PS = 0.346 (−3.73E + 1)	SW = 8.492 (−6.00E − 2) CS = 8.208 (3.31E + 0) PS = 0.284 (−4.85E + 1)	SW = 8.490 (−8.74E − 2) CS = 8.252 (3.86E + 0) PS = 0.238 (−5.69E + 1)	SW = 8.488 (−1.14E − 1) CS = 8.285 (4.27E + 0) PS = 0.203 (−6.32E + 1)

Table 2. Continued

Social Discount Rate	SW: Social Welfare CS: Consumer Surplus PS: Producer Surplus — Consumption Trajectory Optimal for Discount Rate Specified: 0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12
0.08	SW = 7.401 (−1.17E + 0) CS = 5.831 (−1.87E + 1) PS = 1.570 (3.90E + 2)	SW = 7.455 (−4.45E − 1) CS = 6.360 (−1.13E + 1) PS = 1.095 (2.42E + 2)	SW = 7.477 (−1.61E − 1) CS = 6.698 (−6.56E + 0) PS = 0.778 (1.43E + 2)	SW = 7.485 (−4.91E − 2) CS = 6.920 (−3.47E + 0) PS = 0.565 (7.64E + 1)	SW = 7.488 (−8.83E − 3) CS = 7.068 (−1.40E + 0) PS = 0.420 (3.12E + 1	SW = 7.489 (0.00E + 0) CS = 7.168 (0.00E + 0) PS = 0.320 (0.00E + 0)	SW = 7.488 (−5.12E − 3) CS = 7.238 (9.72E − 1) PS = 0.250 (−2.19E + 1)	SW = 7.487 (−1.63E − 2) CS = 7.287 (1.66E + 0) PS = 0.200 (−3.74E + 1)	SW = 7.486 (−2.98E − 2) CS = 7.322 (2.15E + 0) PS = 0.164 (−4.88E + 1)	SW = 7.485 (−4.39E − 2) CS = 7.348 (2.51E + 0) PS = 0.137 (−5.71E + 1)
0.09	SW = 6.604 (−1.20E + 0) CS = 5.258 (−1.91E + 1) PS = 1.346 (6.23E + 2)	SW = 6.652 (−4.78E − 1) CS = 5.731 (−1.18E + 1) PS = 0.921 (3.95E + 2)	SW = 6.671 (−1.92E − 1) CS = 6.030 (−7.19E + 0) PS = 0.641 (2.44E + 2)	SW = 6.679 (−7.21E − 2) CS = 6.225 (−4.20E + 0) PS = 0.455 (1.44E + 2)	SW = 6.682 (−2.26E − 2) CS = 6.353 (−2.23E + 0) PS = 0.330 (7.70E + 1)	SW = 6.684 (−4.16E − 3) CS = 6.439 (−9.05E − 1) PS = 0.245 (3.14E + 1)	SW = 6.684 (0.00E + 0) CS = 6.498 (0.00E + 0) PS = 0.186 (0.00E + 0)	SW = 6.684 (−2.50E − 3) CS = 6.539 (6.28E − 1) PS = 0.145 (−2.20E + 1)	SW = 6.683 (−8.07E − 3) CS = 6.567 (1.07E + 0) PS = 0.116 (−3.76E + 1)	SW = 6.683 (−1.50E − 2) CS = 6.588 (1.39E + 0) PS = 0.095 (−4.90E + 1)
0.10	SW = 5.958 (−1.19E + 0) CS = 4.783 (−1.92E + 1) PS = 1.175 (9.85E + 2)	SW = 6.001 (−4.85E − 1) CS = 5.210 (−1.20E + 1) PS = 0.791 (6.30E + 2)	SW = 6.018 (−2.04E − 1) CS = 5.478 (−7.49E + 0) PS = 0.540 (3.98E + 2)	SW = 6.025 (−8.50E − 2) CS = 5.650 (−4.59E + 0) PS = 0.375 (2.46E + 2)	SW = 6.028 (−3.29E − 2) CS = 5.762 (−2.69E + 0) PS = 0.266 (1.45E + 2)	SW = 6.029 (−1.06E − 2) CS = 5.837 (−1.43E + 0) PS = 0.192 (7.75E + 1)	SW = 6.030 (−1.99E − 3) CS = 5.887 (−5.80E − 1) PS = 0.143 (3.16E + 1)	SW = 6.030 (0.00E + 0) CS = 5.922 (0.00E + 0) PS = 0.108 (0.00E + 0)	SW = 6.030 (−1.24E − 3) CS = 5.945 (4.03E − 1) PS = 0.084 (−2.21E + 1)	SW = 6.030 (−4.04E − 3) CS = 5.962 (6.87E − 1) PS = 0.067 (−3.78E + 1)
0.11	SW = 5.426 (−1.16E + 0) CS = 4.385 (−1.92E + 1) PS = 1.041 (1.55E + 3)	SW = 5.463 (−4.76E − 1) CS = 4.773 (−1.20E + 1) PS = 0.690 (9.95E + 2)	SW = 5.478 (−2.05E − 1) CS = 5.014 (−7.59E + 0) PS = 0.464 (6.35E + 2)	SW = 5.484 (−8.96E − 2) CS = 5.168 (−4.75E + 0) PS = 0.316 (4.01E + 2)	SW = 5.487 (−3.85E − 2) CS = 5.268 (−2.92E + 0) PS = 0.219 (2.48E + 2)	SW = 5.489 (−1.53E − 2) CS = 5.333 (−1.71E + 0) PS = 0.155 (1.46E + 2)	SW = 5.489 (−5.02E − 3) CS = 5.377 (−9.11E − 1) PS = 0.112 (7.79E + 1)	SW = 5.489 (−9.63E − 4) CS = 5.406 (−3.70E − 1) PS = 0.083 (3.18E + 1)	SW = 5.489 (0.00E + 0) CS = 5.426 (0.00E + 0) PS = 0.063 (0.00E + 0)	SW = 5.489 (−6.16E − 4) CS = 5.440 (2.57E − 1) PS = 0.049 (−2.22E + 1)
0.12	SW = 4.979 (−1.12E + 0) CS = 4.047 (−1.91E + 1) PS = 0.933 (2.44E + 3)	SW = 5.013 (−4.59E − 1) CS = 4.401 (−1.20E + 1) PS = 0.612 (1.57E + 3)	SW = 5.026 (−1.98E − 1) CS = 4.621 (−7.57E + 0) PS = 0.405 (1.00E + 3)	SW = 5.032 (−8.88E − 2) CS = 4.760 (−4.79E + 0) PS = 0.272 (6.40E + 2)	SW = 5.034 (−4.01E − 2) CS = 4.849 (−3.01E + 0) PS = 0.185 (4.04E + 2)	SW = 5.035 (−1.77E − 2) CS = 4.907 (−1.85E + 0) PS = 0.128 (2.49E + 2)	SW = 5.036 (−7.21E − 3) CS = 4.945 (−1.09E + 0) PS = 0.091 (1.47E + 2)	SW = 5.036 (−2.42E − 3) CS = 4.970 (−5.77E − 1) PS = 0.065 (7.83E + 1)	SW = 5.036 (−4.71E − 4) CS = 4.988 (−2.35E − 1) PS = 0.048 (3.19E + 1)	SW = 5.036 (0.00E + 0) CS = 4.999 (0.00E + 0) PS = 0.037 (0.00E + 0)

Note. All performance measures are in trillions of dollars. Figures in parentheses are percentage changes relative to the optimal solution for the social discount rate indicated.

ciency losses are apt to be small.

For discount rates in the range of 3% to 12%, performance measures of social welfare (SW), consumer surplus (CS), and producer surplus (PS) are listed in table 2. The entries along the principal diagonal of the table arise when the social discount rate is known and employed. Equations (7), (10), and (11) are used to generate these entries. Off-diagonal entries list performance measures when a discount rate different from the social rate is employed; equations (14), (15), and (16) are used to generate these entries. The figure in parentheses (in exponential notation) beneath each measure indicates the percentage change of the measure from the corresponding social-welfare-maximizing measure. For entries along the principal diagonal, all percentage changes are obviously zero.

For example, for a 3% social discount rate the optimal consumption trajectory is $y_c^{0.03}(t)$ from (4) and SW = \$17.119 trillion (T), consisting of \$11.976 T CS and \$5.144 T PS. For a 5% discount rate the optimal consumption trajectory is $y_c^{0.05}(t)$ and SW = \$11.495 T. If $r = 0.03$ but $w = 0.05$ is used instead, then $y_c^{0.05}(t)$ is suboptimal relative to $y_c^{0.03}(t)$ and using (14) the social welfare for this trajectory is \$17.000 T, consisting of \$13.760 T CS and \$3.239 T PS. These latter entries appear in the third column of the first row. Lost social welfare from using a 5% discount rate instead of the correct 3% rate is thus small—under 1% of the maximum welfare, but the individual surplus measures exhibit much larger absolute and percentage changes: CS rises nearly 15% and PS falls 37%. Similarly, if the true discount rate is 5% but a 3% rate is used instead, then social welfare stands at \$11.426 T, a reduction of only 0.6% from the maximum level. But again, the individual surplus measures experience much larger absolute and percentage changes.

For $r = 0.03$, lost SW increases in percentage terms as w increases. For example, if $w = 0.10$ is used instead, 2.5% of maximum welfare is lost, while CS and PS increase and decrease, respectively, by relatively large proportions. The directional changes to the surplus measures are readily explained. Raising the discount rate reduces near-term user costs in (6) and thus brings the efficient near-term prices closer to marginal cost α, in turn reducing near-term PS and increasing near-term CS. With the higher discount rate, prices rise faster later in time and the adjustments to the surplus measures are reversed. But in present value terms, these distant-term adjustments do not offset the near-term adjustments. Thus surplus is transferred from producers to consumers.

Similar types of adjustments occur for different values of r. When $r \geq 0.06$, if the wrong discount rate deviates no more than three percentage points from the social rate, then lost SW is small—under 1%. Moreover, as the social rate increases, percentage SW losses from using the wrong rate shrink. For higher rates the changes in SW are minuscule because the gains and losses of the two surplus measures are largely offsetting. Furthermore, as suggested by table 1, optimal consumption trajectories for discount rates in the range of 9% to 12% exhibit nearly identical social welfare levels. For such rates the user cost premium of (6) shrinks in the near term, the efficient trajectory approaches the marginal-cost pricing trajectory in the near term, and the present value of producer surplus approaches zero. Distant-term misallocations count little because of the high discount rate.

One further inference is possible. The social welfare losses of using a discount rate double or triple the social rate shrink in percentage terms as the social rate rises. For instance, the welfare losses of using a discount rate twice the social rates of 3%, 4%, 5%, and 6% are, respectively, 1.15%, 0.74%, 0.45%, and 0.27%. The welfare losses of using a discount rate triple the social rates of 3% and 4% are, respectively, 2.23% and 1.36%.

The largest percentage welfare loss (2.92%) occurs when a 12% rate is used, but the social rate is 3%. This result and others imply that, as long as the social rate lies in the range of 3% to 12%, the ten consumption trajectories of table 1 are all near optimal.

That many solutions may be near optimal for a depletable resource model is plausible but not necessarily intuitive. Consider the following modifications to the welfare-maximizing trajectory $y_c^r(t)$. If at time t_1 consumption is reduced by a small amount Δ, then net surplus declines during t_1. But Δ is available to augment consumption at some other time t_2, thereby increasing net surplus. The resulting consumption trajectory must yield lower social welfare than $y_c^r(t)$, but intuition alone cannot predict whether these adjustments reduce welfare by a little or by a lot. An identical argument holds for other similar adjustments to $y_c^r(t)$. Only a numerical approach can determine the size of the losses. Rowse (1988) argues that the reduction to social welfare of deviating from the optimal depletion trajectory—even substantially—may be small, much smaller than the current emphasis on ef-

ficiency in the literature would implicitly suggest.

Sensitivity Analysis

To explore the sensitivity of the results, the analysis is replicated by decreasing the stock size by 90% to 118.9 billion barrels and increasing the demand extinction price β_2 to \$100 per barrel. The increase in β_2 constitutes a substantial outward shift of the linear WTP function (each intercept increases by a third) and, if crude is priced at the marginal cost of \$20 per barrel to exhaustion, the stock lasts only 118.9/32 = 3.72 years, compared with 54.05 years previously. Furthermore, the rise in β_2 represents a rise in the cost of backstop supplies to five times the marginal cost of conventional crude.

Table 3 specifies the character of the new optimal consumption trajectories. Exhaustion occurs much sooner for all trajectories, and the relative differences among them are much greater than before. For instance, for a 3% social discount rate, exhaustion occurs at year 17.08; while for a 12% rate, exhaustion occurs at year 9.33. It is also apparent that user costs for all trajectories are substantial at $t = 0$.

Table 4 indicates the social welfare losses from using the wrong discount rate. Although the percentage losses are larger than before, the changes are surprisingly muted. For instance, if the social rate is 3% but a 10% rate is used instead, welfare is reduced by only 4.48%, less than double the base case loss. In view of the more stringent supply circumstances, this loss is remarkably small. As before, in absolute and percentage terms the transfers between *CS* and *PS* are much larger between solutions than the changes to *SW*. Moreover, similar patterns recur. If $r \geq 0.06$, then deviations of no more than 3% from the social rate reduce welfare by 2% or less. Furthermore, if $r \geq 0.08$, percentage losses are under 1% if the wrong rate deviates by no more than 3% from the social rate. Finally, using a discount rate double or triple the social rate yields losses that shrink in percentage terms as the social rate rises.

Concluding Comments

In this paper the social welfare implications of using the wrong discount rate to allocate an exhaustible resource were examined using a simple numerical model. Principal findings are (*a*) the percentage welfare loss is small if the wrong rate is close to the social rate, but even discount rates differing from the social rate by as much as 3% reduce welfare very little; (*b*) the losses are dominated in absolute and percentage terms by the transfers of surplus between consumers and producers; and (*c*) the percentage losses from using a discount rate double or triple the social rate shrink as the social rate rises.

Given the heterogenous circumstances of different depletable resources, the question addressed in this paper may not have a single unambiguous answer. Yet, several arguments favor the generality of the findings. First, the sensitivity analysis represents an extreme case of supply stringency and still yields small percentage welfare losses from using the wrong discount rate. It is unlikely that a more elaborate model exhibiting much less stringent supply circumstances could yield large welfare losses from using an improper rate. Second, the results arise because there are many near-optimal solutions to the depletion problems considered (Rowse 1988). Hence, adopting a more elaborate computational framework may not yield different results. Finally, analysis with a computationa

Table 3. Character of the Optimal Consumption Trajectories for the Sensitivity Analysis

Discount Rate	Exhaustion Year	Initial Price (\$/Barrel)	Efficient Consumption Rate (10^9 Barrels/Year) at Year 0	1	2	4	6	8	10	12	14
0.03	17.08	67.92	12.83	12.25	11.65	10.39	9.05	7.63	6.12	4.52	2.83
0.04	14.99	63.92	14.43	13.71	12.97	11.38	9.67	7.80	5.79	3.61	1.24
0.05	13.57	60.60	15.76	14.93	14.05	12.17	10.08	7.77	5.23	2.41	0.00
0.06	12.52	57.75	16.90	15.97	14.98	12.80	10.36	7.60	4.49	0.98	0.00
0.07	11.71	55.26	17.90	16.88	15.78	13.34	10.54	7.31	3.60	0.00	0.00
0.08	11.05	53.04	18.78	17.68	16.49	13.80	10.64	6.93	2.58	0.00	0.00
0.09	10.51	51.06	19.58	18.41	17.13	14.19	10.68	6.48	1.44	0.00	0.00
0.10	10.06	49.26	20.30	19.07	17.70	14.54	10.67	5.95	0.19	0.00	0.00
0.11	9.67	47.62	20.95	19.67	18.23	14.85	10.62	5.36	0.00	0.00	0.00
0.12	9.33	46.12	21.55	20.22	18.72	15.12	10.54	4.72	0.00	0.00	0.00

Table 4. Performance Measures for the Sensitivity Analysis

Social Discount Rate	SW: Social Welfare — CS: Consumer Surplus — PS: Producer Surplus Consumption Trajectory Optimal for Discount Rate Specified									
	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12
0.03	SW = 6.860	SW = 6.841	SW = 6.803	SW = 6.755	SW = 6.705	SW = 6.653	SW = 6.602	SW = 6.553	SW = 6.504	SW = 6.457
	(0.00E + 0)	(−2.65E − 1)	(−8.31E − 1)	(−1.52E + 0)	(−2.26E + 0)	(−3.01E + 0)	(−3.75E + 0)	(−4.48E + 0)	(−5.18E + 0)	(−5.86E + 0)
	CS = 1.162	CS = 1.335	CS = 1.481	CS = 1.609	CS = 1.723	CS = 1.826	CS = 1.919	CS = 2.005	CS = 2.084	CS = 2.158
	(0.00E + 0)	(1.49E + 1)	(2.75E + 1)	(3.85E + 1)	(4.83E + 1)	(5.72E + 1)	(6.52E + 1)	(7.26E + 1)	(7.94E + 1)	(8.58E + 1)
	PS = 5.698	PS = 5.507	PS = 5.321	PS = 5.146	PS = 4.982	PS = 4.828	PS = 4.683	PS = 4.548	PS = 4.420	PS = 4.299
	(0.00E + 0)	(−3.36E + 0)	(−6.61E + 0)	(−9.69E + 0)	(−1.26E + 1)	(−1.53E + 1)	(−1.78E + 1)	(−2.02E + 1)	(−2.24E + 1)	(−2.45E + 1)
0.04	SW = 6.488	SW = 6.508	SW = 6.496	SW = 6.470	SW = 6.436	SW = 6.399	SW = 6.359	SW = 6.320	SW = 6.280	SW = 6.241
	(−2.98E − 1)	(0.00E + 0)	(−1.77E − 1)	(−5.81E − 1)	(−1.10E + 0)	(−1.68E + 0)	(−2.28E + 0)	(−2.89E + 0)	(−3.50E + 0)	(−4.10E + 0)
	CS = 1.114	CS = 1.285	CS = 1.431	CS = 1.558	CS = 1.671	CS = 1.773	CS = 1.865	CS = 1.951	CS = 2.030	CS = 2.103
	(−1.33E + 1)	(0.00E + 0)	(1.13E + 1)	(2.12E + 1)	(3.00E + 1)	(3.79E + 1)	(4.51E + 1)	(5.18E + 1)	(5.79E + 1)	(6.36E + 1)
	PS = 5.375	PS = 5.222	PS = 5.065	PS = 4.912	PS = 4.765	PS = 4.626	PS = 4.494	PS = 4.369	PS = 4.250	PS = 4.138
	(2.91E + 0)	(0.00E + 0)	(−3.01E + 0)	(−5.94E + 0)	(−8.75E + 0)	(−1.14E + 1)	(−1.39E + 1)	(−1.63E + 1	(−1.86E + 1)	(−2.08E + 1)
0.05	SW = 6.147	SW = 6.198	SW = 6.210	SW = 6.202	SW = 6.183	SW = 6.158	SW = 6.129	SW = 6.099	SW = 6.067	SW = 6.035
	(−1.02E + 0)	(−1.93E − 1)	(0.00E + 0)	(−1.28E − 1)	(−4.31E − 1)	(−8.36E − 1)	(−1.30E + 0)	(−1.79E + 0)	(−2.30E + 0)	(−2.82E + 0)
	CS = 1.069	CS = 1.239	CS = 1.383	CS = 1.509	CS = 1.621	CS = 1.722	CS = 1.814	CS = 1.899	CS = 1.978	CS = 2.051
	(−2.27E + 1)	(−1.04E + 1)	(0.00E + 0)	(9.11E + 0)	(1.72E + 1)	(2.45E + 1)	(3.12E + 1)	(3.73E + 1)	(4.30E + 1)	(4.83E + 1)
	PS = 5.078	PS = 4.959	PS = 4.827	PS = 4.693	PS = 4.562	PS = 4.436	PS = 4.315	PS = 4.200	PS = 4.089	PS = 3.984
	(5.19E + 0)	(2.74E + 0)	(0.00E + 0)	(−2.77E + 0)	(−5.49E + 0)	(−8.10E + 0)	(−1.06E + 1)	(−1.30E + 1)	(−1.53E + 1)	(−1.75E + 1)
0.06	SW = 5.832	SW = 5.910	SW = 5.943	SW = 5.951	SW = 5.945	SW = 5.931	SW = 5.911	SW = 5.889	SW = 5.864	SW = 5.839
	(−1.99E + 0)	(−6.79E − 1)	(−1.37E − 1)	(0.00E + 0)	(−9.64E − 2)	(−3.33E − 1)	(−6.58E − 1)	(−1.04E + 0)	(−1.45E + 0)	(−1.88E + 0)
	CS = 1.027	CS = 1.195	CS = 1.338	CS = 1.462	CS = 1.573	CS = 1.674	CS = 1.765	CS = 1.849	CS = 1.927	CS = 2.000
	(−2.97E + 1)	(−1.83E + 1)	(−8.53E + 0)	(0.00E + 0)	(7.60E + 0)	(1.45E + 1)	(2.07E + 1)	(2.65E + 1)	(3.18E + 1)	(3.68E + 1)
	PS = 4.805	PS = 4.715	PS = 4.605	PS = 4.488	PS = 4.371	PS = 4.257	PS = 4.146	PS = 4.039	PS = 3.937	PS = 3.839
	(7.05E + 0)	(5.06E + 0)	(2.60E + 0)	(0.00E + 0)	(−2.60E + 0)	(−5.15E + 0)	(−7.62E + 0)	(−1.00E + 1)	(−1.23E + 1)	(−1.45E + 1)
0.07	SW = 5.542	SW = 5.643	SW = 5.692	SW = 5.714	SW = 5.720	SW = 5.716	SW = 5.705	SW = 5.690	SW = 5.672	SW = 5.652
	(−3.11E + 0)	(−1.36E + 0)	(−4.89E − 1)	(−1.02E − 1)	(0.00E + 0)	(−7.55E − 2)	(−2.66E − 1)	(−5.31E − 1)	(−8.47E − 1)	(−1.20E + 0)
	CS = 0.988	CS = 1.154	CS = 1.295	CS = 1.418	CS = 1.528	CS = 1.628	CS = 1.718	CS = 1.802	CS = 1.879	CS = 1.951
	(−3.53E + 1)	(−2.45E + 1)	(−1.53E + 1)	(−7.20E + 0)	(0.00E + 0)	(6.51E + 0)	(1.24E + 1)	(1.79E + 1)	(2.30E + 1)	(2.77E + 1)
	PS = 4.554	PS = 4.489	PS = 4.398	PS = 4.296	PS = 4.192	PS = 4.088	PS = 3.987	PS = 3.888	PS = 3.793	PS = 3.701
	(8.64E + 0)	(7.09E + 0)	(4.91E + 0)	(2.49E + 0)	(0.00E + 0)	(−2.48E + 0)	(−4.90E + 0)	(−7.25E + 0)	(−9.53E + 0)	(−1.17E + 1)

Table 4. Continued

SW: Social Welfare CS: Consumer Surplus PS: Producer Surplus

Social Discount Rate	Consumption Trajectory Optimal for Discount Rate Specified: 0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12
0.08	SW = 5.274	SW = 5.393	SW = 5.458	SW = 5.492	SW = 5.508	SW = 5.512	SW = 5.509	SW = 5.500	SW = 5.488	SW = 5.473
	(−4.32E + 0)	(−2.16E + 0)	(−9.91E − 1)	(−3.70E − 1)	(−7.92E − 2)	(0.00E + 0)	(−6.08E − 2)	(−2.17E − 1)	(−4.38E − 1)	(−7.05E − 1)
	CS = 0.951	CS = 1.115	CS = 1.254	CS = 1.376	CS = 1.485	CS = 1.583	CS = 1.673	CS = 1.756	CS = 1.833	CS = 1.904
	(−3.99E + 1)	(−2.96E + 1)	(−2.08E + 1)	(−1.31E + 1)	(−6.22E + 0)	(0.00E + 0)	(5.68E + 0)	(1.09E + 1)	(1.57E + 1)	(2.02E + 1)
	PS = 4.323	PS = 4.279	PS = 4.204	PS = 4.116	PS = 4.023	PS = 3.929	PS = 3.836	PS = 3.744	PS = 3.655	PS = 3.569
	(1.00E + 1)	(8.90E + 0)	(7.00E + 0)	(4.76E + 0)	(2.40E + 0)	(0.00E + 0)	(−2.37E + 0)	(−4.70E + 0)	(−6.96E + 0)	(−9.15E + 0)
0.09	SW = 5.026	SW = 5.161	SW = 5.238	SW = 5.283	SW = 5.308	SW = 5.320	SW = 5.323	SW = 5.320	SW = 5.313	SW = 5.304
	(−5.58E + 0)	(−3.05E + 0)	(−1.60E + 0)	(−7.58E − 1)	(−2.90E − 1)	(−6.33E − 2)	(0.00E + 0)	(−4.99E − 2)	(−1.80E − 1)	(−3.67E − 1)
	CS = 0.917	CS = 1.078	CS = 1.215	CS = 1.336	CS = 1.444	CS = 1.541	CS = 1.630	CS = 1.712	CS = 1.788	CS = 1.859
	(−4.38E + 1)	(−3.39E + 1)	(−2.55E + 1)	(−1.81E + 1)	(−1.14E + 1)	(−5.46E + 0)	(0.00E + 0)	(5.03E + 0)	(9.69E + 0)	(1.40E + 1)
	PS = 4.109	PS = 4.083	PS = 4.023	PS = 3.947	PS = 3.864	PS = 3.778	PS = 3.693	PS = 3.608	PS = 3.525	PS = 3.445
	(1.13E + 1)	(1.06E + 1)	(8.94E + 0)	(6.88E + 0)	(4.64E + 0)	(2.32E + 0)	(0.00E + 0)	(−2.29E + 0)	(−4.54E + 0)	(−6.72E + 0)
0.10	SW = 4.796	SW = 4.944	SW = 5.032	SW = 5.086	SW = 5.118	SW = 5.137	SW = 5.147	SW = 5.149	SW = 5.147	SW = 5.141
	(−6.86E + 0)	(−3.99E + 0)	(−2.28E + 0)	(−1.24E + 0)	(−6.00E − 1)	(−2.33E − 1)	(−5.17E − 2)	(0.00E + 0)	(−4.17E − 2)	(−1.52E − 1)
	CS = 0.884	CS = 1.043	CS = 1.178	CS = 1.298	CS = 1.404	CS = 1.501	CS = 1.589	CS = 1.670	CS = 1.745	CS = 1.816
	(−4.71E + 1)	(−3.76E + 1)	(−2.94E + 1)	(−2.23E + 1)	(−1.59E + 1)	(−1.01E + 1)	(−4.86E + 0)	(0.00E + 0)	(4.51E + 0)	(8.70E + 0)
	PS = 3.912	PS = 3.901	PS = 3.853	PS = 3.788	PS = 3.714	PS = 3.636	PS = 3.558	PS = 3.479	PS = 3.402	PS = 3.326
	(1.24E + 1)	(1.21E + 1)	(1.08E + 1)	(8.88E + 0)	(6.76E + 0)	(4.52E + 0)	(2.26E + 0)	(0.00E + 0)	(−2.22E + 0)	(−4.40E + 0)
0.11	SW = 4.583	SW = 4.741	SW = 4.838	SW = 4.900	SW = 4.939	SW = 4.964	SW = 4.979	SW = 4.986	SW = 4.988	SW = 4.987
	(−8.13E + 0)	(−4.96E + 0)	(−3.02E + 0)	(−1.78E + 0)	(−9.85E − 1)	(−4.86E − 1)	(−1.92E − 1)	(−4.30E − 2)	(0.00E + 0)	(−3.53E − 2)
	CS = 0.854	CS = 1.010	CS = 1.143	CS = 1.261	CS = 1.367	CS = 1.462	CS = 1.549	CS = 1.630	CS = 1.704	CS = 1.774
	(−4.99E + 1)	(−4.08E + 1)	(−3.29E + 1)	(−2.60E + 1)	(−1.98E + 1)	(−1.42E + 1)	(−9.09E + 0)	(−4.37E + 0)	(0.00E + 0)	(4.07E + 0)
	PS = 3.729	PS = 3.731	PS = 3.694	PS = 3.638	PS = 3.573	PS = 3.502	PS = 3.429	PS = 3.356	PS = 3.284	PS = 3.213
	(1.36E + 1)	(1.36E + 1)	(1.25E + 1)	(1.08E + 1)	(8.79E + 0)	(6.64E + 0)	(4.43E + 0)	(2.20E + 0)	(0.00E + 0)	(−2.17E + 0)
0.12	SW = 4.385	SW = 4.551	SW = 4.656	SW = 4.724	SW = 4.770	SW = 4.800	SW = 4.819	SW = 4.831	SW = 4.837	SW = 4.839
	(−9.38E + 0)	(−5.94E + 0)	(−3.78E + 0)	(−2.37E + 0)	(−1.43E + 0)	(−8.03E − 1)	(−4.02E − 1)	(−1.60E − 1)	(−3.63E − 2)	(0.00E + 0)
	CS = 0.825	CS = 0.978	CS = 1.110	CS = 1.226	CS = 1.330	CS = 1.425	CS = 1.511	CS = 1.591	CS = 1.665	CS = 1.733
	(−5.24E + 1)	(−4.36E + 1)	(−3.60E + 1)	(−2.92E + 1)	(−2.32E + 1)	(−1.78E + 1)	(−1.28E + 1)	(−8.22E + 0)	(−3.97E + 0)	(0.00E + 0)
	PS = 3.560	PS = 3.573	PS = 3.546	PS = 3.498	PS = 3.439	PS = 3.375	PS = 3.308	PS = 3.240	PS = 3.172	PS = 3.105
	(1.46E + 1)	(1.51E + 1)	(1.42E + 1)	(1.26E + 1)	(1.08E + 1)	(8.68E + 0)	(6.53E + 0)	(4.34E + 0)	(2.16E + 0)	(0.00E + 0)

Note. All performance measures are in trillions of dollars. Figures in parentheses are percentage changes relative to the optimal solution for the social discount rate indicated.

model embodying several important real-world complexities yields similar findings (Rowse 1989).

Although no firm claim of generality can be asserted, the results offer some comfort to practitioners because the efficiency losses from using a rate not too different from the social rate appear small. Yet the substantial transfers of surplus between consumers and producers when the wrong rate is used imply that income distribution considerations may bear on the discount rate choice. More generally, because most exhaustible resource allocation problems are actually multicriterion problems and not single-criterion problems, the findings also suggest that the current emphasis on maximizing conventional social welfare in exhaustible resource models should be widened to embrace secondary and tertiary criteria. Alternatively, maximizing the sum of consumer plus producer surplus as the only social welfare goal may be a frail reed to lean upon for allocating an exhaustible resource among competing generations of consumers.

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On the Political Economy of Public Good Inputs in Agriculture

Harry de Gorter and David Zilberman

The paper analyzes two elements in explaining and prescribing the level of cost-reducing "public good" inputs in agriculture: the distribution of political influence and the economic properties of markets. The incidence of costs/benefits of alternative cost-sharing arrangements between taxpayers and producers is compared to the social optimal and competitive outcomes. Although one group could lose, we focus only on situations of a Pareto improvement. The model predicts why some sectors have relatively more public versus private research funding and why the degree of underinvestment varies across sectors. The observed underinvestment in agriculture may be due to the political power of farmers, inelastic demand, and highly productive public good inputs.

Key words: political economy, public good inputs, public versus private financing.

Agriculture employs cost-reducing inputs that are "public goods," including direct technological inputs (research and development—R&D), the production and distribution of knowledge (information and education), and water facilities (dams and canals). A standard conclusion is that underinvestment in such public good inputs will occur under perfect competition because individual firms cannot appropriate the entire economic benefit. This has led to the emergence of other institutional arrangements to provide the public goods in agriculture including government provision financed by general tax revenues and farm group "collusion." The latter includes instances where growers' associations finance and manage the provision of public goods, leading to collective action in the input market but not necessarily in the output market.[1]

This paper analyzes and evaluates the choice of public good input levels under these alternative arrangements from a political economy perspective.[2] Studies on the economics of public good inputs have focused mostly on the impact of imperfect market structure on R&D perfor mance (Kamien and Schwartz). Little attentio has been given to conceptual analysis of the im pact of alternative political situations and insti tutional arrangements on the provision of publi good inputs in competitive industries. These lat ter issues are especially relevant for the agri cultural sector. Indeed, empirical evidence o returns from public research in agriculture le Ruttan to conclude that there is a significant un derinvestment in such research and suggested tha political economy considerations affect the leve of this research.

The framework presented here will attempt t explain these observations by considering thre alternative scenarios. In two of the cases ex amined, the taxpayers finance the provision o the public good.[3] In one of these, the determi nation of the quantity of the public good is con trolled by consumers and, in the other, it is con trolled by producers. These two polar cases se a bound on all possible outcomes whereby th public good is financed by the taxpayer. The thir case is when the producers both finance the pro vision of the public good and determine it quantity. For each of these cases, the resultin level of the public good and distribution of wel fare between groups are compared to the socia optimum and the competitive case with no gov ernment intervention.

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[1] Marketing orders and agreements are often used as legal vehicles to overcome antitrust problems. The many check-off programs at the state and national level for soybeans, corn, and beef are examples of cooperation to invest in R&D.

[2] Gardner and Rausser presented general frameworks for analyzing the political economy of agricultural policies. Studies generating evidence that political and institutional factors are responsible for this suboptimal allocation of resources in agriculture include Guttman, and Huffman and Miranowski.

[3] Consumers and taxpayers are assumed to be identical in thi paper.

The Model

The analysis uses a deterministic, static, and partial-equilibrium model of a closed economy with competitive market conditions. Suppose that consumer preferences are represented by the separable additive utility function $U(q, Z) = U(q) + Z$, where q is the good under consideration and Z is the *numèraire* good. The marginal utility of consuming q is positive and declining, $U_q > 0$, $U_{qq} < 0$.

The cost function facing the industry, $C(q, E)$, depends on output, q, and public good expenditure, E. The marginal cost of output is assumed positive and increasing ($C_q > 0$, $C_{qq} > 0$), and cost is convex in both E and q ($C_{EE} \geq 0$, $C_{EE}C_{qq} - C_{qE} > 0$). It is also assumed that the marginal impact of the public good on cost is nonincreasing with the level of operation ($C_{Eq} \leq 0$). If the public good affects only the fixed cost of production, then $C_{qE} = 0$; if an increase in E reduces variable cost, then $C_{qE} < 0$. To consider alternative scenarios on the incidence of burden of public good expenditures, let α denote the share of the public good expenditure paid by consumers. If the government provides the public good using the taxpayers' money, then $\alpha = 1$. If, however, the firms in the industry collude and finance the public good provision themselves, then $\alpha = 0$. Assume that individual consumers and producers consider α and E as given in determining their consumption and production choices. Thus, consumers would choose q to maximize $U(q, Y - pq - \alpha E)$, where p is output price and Y is income, and producers would choose q to maximize $pq - C(q, E) - E(1 - \alpha)$. The resulting demand and supply relationships are, respectively, $q = D(p) \equiv U_q^{-1}(p)$ and $q = S(p, E) \equiv C_q^{-1}(p, E)$, where D is demand and S is supply. Equilibrium in the product market is obtained when marginal cost equals marginal utility, $C_q = U_q$; thus, equilibrium price and quantities are functions of the public good expenditure and are denoted by $q^*(E)$ and $p^*(E)$.

The marginal effect of an increase in public good expenditures on output is obtained by total differentiation of the first-order condition to yield

$$(1) \qquad q_E^* = \frac{C_{qE}}{U_{qq} - C_{qq}} = \frac{C_{qE}\,\eta^S\eta^D \cdot q^*}{p(\eta^S - \eta^D)},$$

where $\eta^S \equiv S_p \cdot p/q = p/(C_{qq} \cdot q)$ denotes price elasticity of supply and $\eta^D = D_p \cdot p/q = p/(U_{qq} \cdot q)$ denotes price elasticity of demand. Using equation (1) and the total differentiation of the consumer decision rule, $U_q = p$, yields an expression describing the marginal impact of change in public good expenditures on output price,

$$(2) \qquad p_E^* = \frac{C_{qE}}{1 - \eta^D/\eta^S}.$$

The magnitude of the change in price depends on the magnitude of the marginal impact of public good expenditures on marginal cost ($|C_{qE}|$); thus, a larger $|C_{qE}|$ results in a greater horizontal shift in supply, a greater increase in output, and a greater reduction in output price. An increase in public good expenditure will have a stronger output price effect and a weaker output effect as the elasticity of demand is smaller (in absolute value) and a smaller price and output effect as supply is more inelastic.

Introducing $q^*(E)$ and $p^*(E)$ into the profit and utility functions yields equilibrium utility (U) and profit (π) as functions of the public good expenditure, namely, $U^*(E) \equiv U[q^*(E)] + Y - p^*(E)q^*(E) - \alpha E$ and $\pi^*(E) \equiv p^*(E)\, q^*(E) - C[q^*(E), E] - (1 - \alpha)E$.

Differentiation of these functions with respect to the public good expenditure, using $C_q = U_q$ and equations (1) and (2), yields[4]

$$(3) \qquad U_E^* = -q^* p_E^* - \alpha = -C_E \frac{\varepsilon^q}{1 - \eta^D/\eta^S} - \alpha, \text{ and}$$

$$(4) \qquad \pi_E^* = -C_E + q^* p_E^* - (1 - \alpha) = -C_E\left[1 - \frac{\varepsilon^q}{1 - \eta^D/\eta^S}\right] - (1 - \alpha),$$

where $\varepsilon^q = C_{qE} \cdot q/C_E$ is the output elasticity of the marginal impact of the public good on cost.[5] This elasticity, ε^q, is nonnegative; it equals zero when the public good affects the fixed cost of production. However, it may be larger than 1 when the public good affects the variable cost.

[4] To obtain (3), totally differentiate $U^*(E) = U[q^*(E)] + Y - P^*(E)\, q^*(E) - \alpha E$ with respect to E to obtain $(dU^*)/(dE) = -q^*(dP)/(dE) - \alpha$. Then, substituting for $(dP)/(dE)$ from equation (2) which is obtained by totally differentiating the consumer decision rule, $U_q(q) = P(q)$, and solving gives $(dP)/(dq) = U_{qq}$. Total differentiation of the product market equilibrium, $C_q = U_q$, gives $(dq)/(dE) = (C_{qE})/(U_{qq} - C_{qq})$. Combining this with the previous expression for $(dP)/(dq)$ generates equation (2) which is substituted into the expression earlier for $(dU^*)/(dE)$ to give the final form of equation (3) in the text. A similar procedure for the producer decision problem will yield the result reported in equation (4).

[5] Substituting equation (2) into the middle expression of (3) gives $U_E^* = -q^*[(C_{qE})/(1 - \eta^D/\eta^S)] - \alpha$. Multiplying by $(C_E)/(C_E)$ gives the right-hand term in (3) where $\varepsilon^q = (q^* C_{qE})/(C_E)$.

For example, if the cost function is multiplicative and separable in q and E, $C(q, E) = h(q) \cdot q(E)$; then $\varepsilon^q = h_q\, q/h(q) > 1$ by the convexity of the cost function. If the cost function is additive in q and E, $C(q, E) = h(q) - q(E)$; then $\varepsilon^q = 0$.

A marginal increase in the public good input expenditure has four effects. It has a cost-reducing effect measured by $-C_E$; a price-reducing effect equal to the marginal decline in price times the quantity, $q^* p_E^*$; and a consumers' expenditure effect which equals α and a producers' expenditure effect of $1 - \alpha$. Equation (3) suggests that the marginal impact on consumers of an increase in the public good input is the difference between the price-reduction effect, $q^* p_E^*$, and the consumers' expenditure effect, α. Equation (4) suggests that the marginal impact on the producers' welfare of an increase in the public good is the difference between the cost-reducing effect and the sum of the price-reducing effect and the producers' expenditure effect.

When producers control the provision of this public good input, $\pi^*(E)$ is maximized, while $U^*(E)$ is maximized when consumers have the power or influence to determine the level of E. The welfare evaluation of outcomes under alternative institutional arrangements is obtained by using the total surplus function, $W^*(E) \equiv U^*(E) + \pi^*(E)$. This is an appropriate welfare standard because, given resources, Y, and technology, $C(q, E)$, utility from consumption is $W(q, E) = U(q) + Y - E - C(q, E)$. For each E, $W(q, E)$ is maximized when $C_q = U_q$; hence, q behaves according to $q^*(E)$. Welfare as a function of E is given by $W(q^*, E) = U(q^*) + Y - \alpha E + p(q^*)\, q^* - p(q^*)\, q^* - C(q^*, E) - (1 - \alpha) E = U^*(E) + \pi^*(E)$. Differentiation of the welfare criteria function yields

$$W_E^* = -C_E - 1. \tag{5}$$

The optimal public good expenditure occurs at a level where the marginal cost-reduction effect equals the marginal expenditure.

Incidence of Cost/Benefits Under Alternative Allocation Mechanisms

The implications of three alternative allocation mechanisms are examined in this section. Comparisons are made to (*a*) the competitive outcome without the public good and (*b*) the social optimum. The cases considered are the following. (*a*) The government finances the public good via a consumer income tax, and producers determine or influence its level. In this case $\alpha = 1$, and E is determined by maximizing $\pi^*(E)$. This situation has the government providing the public good, while the administrators in charge are being "captured" by producers in the industry. (*b*) Consumers finance the public good through general taxation but determine its level. In this case $\alpha = 1$, and E is determined by maximizing $U^*(E)$. This is the case where government administrators are captured by consumer groups in allocating the level of public good inputs. (*c*) Producers finance the public good and determine its level. In this case $\alpha = 0$, and E is determined by maximizing $\pi^*(E)$. This situation results from collective action by producers in providing the public good.

Because $W^*(E) = \pi^*(E) + U^*(E)$, evaluating π_E^* and U_E^* (which must have opposite signs at the social optimum, E^*) determines the level of the producer optimum, E_1^* relative to the consumer optimum, E_2^*. Because $-C_E - 1 = 0$ at E^*, conditions (3) and (4) yield $U_E^* = -q^* p_E^* - \alpha = -\pi_E^*$ (at E^*). Hence, E_1^* and E_2^* bounds E^* with $E_1^* \gtrless E_2^*$ as $-q^* p_E^* \lesseqgtr \alpha$ at $E^* > 0$. Namely, consumers' (producers') optimum is larger than social optimum which, in turn, is larger than producers' (consumers') optimum if at the social optimum the reduction in consumers' expenditures associated with a marginal increase in E ($-q^* p_E^*$) is larger (smaller) than consumers' share of the marginal expenditure (α). Thus, $E_2^* > E^* > E_1^*$ is more likely to occur with a smaller value of α and a more inelastic demand (via p_E^*). Obviously, when producers finance the public good ($\alpha = 0$), and it tends to reduce price, E_2^* ($= \infty$) $> E^* > E_1^*$. If a perfectly elastic demand curve exists then $E_2^* = 0$ for all values of α (while $E_1^* = 0$ if $\alpha = 1$). The incidence of economic costs benefits is analyzed in detail in the following subsections for each of these cost-sharing mechanisms under alternative economic conditions.

Consumers Finance the Public Good; Producers Determine Its Quantity

Let E^1 denote the public good expenditure in this case. It is nonnegative and maximizes the producers' profit for $\alpha = 1$. In this case the marginal impact of an increase in the public good expenditure on the producers' profit is the difference between the cost-reduction effect and the price-reduction effect. Using equation (4),

$$(6) \qquad \pi_E^* = -C_E + q^* p_E^* = -C_E\left[1 - \frac{\varepsilon^q}{1 - \eta^D/\eta^S}\right].$$

Assuming concavity of profit in E and q, the public good will be provided ($E^1 > 0$) as $1 - \eta^D/\eta^S > \varepsilon^q$. The exact quantity of the public good is determined at a level where the marginal price-reduction effect ($q^* p_E^*$) equals the marginal cost-reduction effect ($-C_E$). Equation (6) also indicates that the public good expenditures increase as the elasticity of demand is increasing (in absolute value), the elasticity of supply is decreasing, and the output elasticity of the marginal impact of the public good on cost is decreasing. Thus, when producers control the public good provision, more money will be spent on the public good when (*a*) E has a stronger impact in reducing fixed costs as opposed to variable costs, (*b*) the industry is facing a more elastic demand curve, and (*c*) the industry lacks the flexibility to adjust its production capacity in response to changes in economic conditions.

Consumers Finance the Public Good and Determine Its Quantity

Let E^2 denote the public good expenditure in this case. It is nonnegative and maximizes consumers' welfare for $\alpha = 1$. Using (3), in this case the marginal impact of an increase in public expenditures on consumer welfare is the difference between the price-reduction effect of a marginal increase in public good expenditures and the expenditure itself, i.e.,

$$(7) \quad U_E^* = -q^* p_E^* - 1 = -C_E\frac{\varepsilon^q}{1 - \eta^D/\eta^S} - 1.$$

Assuming concavity of consumer welfare in E, equation (7) implies that the optimal quantity of the public good is determined by equating the marginal price-reducing effect with the marginal expenditure (at $E^2 > 0$, $-q^* p_E^* = 1$). Hence, the optimal outcome can be summarized by $E^2 > 0$ as $-C_E > (1 - \eta^D/\eta^S)/(\varepsilon^q)$.

Because $C_E < 0$, it follows that public good expenditures increase as the elasticity of demand is decreasing, the elasticity of supply is increasing, and the output elasticity of the marginal impact of public good on cost is increasing. Thus, consumers will not support any level of public good expenditure if the demand is infinitely elastic, supply is inelastic, or the public good affects fixed cost and not variable cost. On the other hand, when demand is inelastic and the public good expenditure has a strong impact on variable cost in shifting supply to the right, a relatively large volume of public good expenditures will be supported by consumers.

Comparison of Consumer, Producer, and Social Optima: Consumers Finance the Public Good

One can compare E^1, E^2, and E^* under myriad assumptions regarding political power distributions and demand and supply elasticities. The discussion will be limited to situations where the introduction of the public good input improves the welfare of both producers and consumers. Such situations represent a real (not potential) Pareto improvement over the "laissez-faire" case and are more likely to occur and persist than situations when one of the groups is losing relative to no intervention (for a detailed analysis, see de Gorter).

The functions $\tilde{\pi}(E) = \pi^*(E) - \pi^*(0)$, $\tilde{U}(E) = U^*(E) - U^*(0)$, and $\tilde{W}(E) = W^*(E) - W(0)$ denote the welfare gains to producers, consumers, and society, respectively, from the provision of public good inputs. Figure 1 depicts the possible outcomes for scenarios where both $U_E^*(0)$ and $\pi_E^*(0)$ are positive. For small E's, all functions are increasing, and $\tilde{W}$ is larger than both $\tilde{U}$ and $\tilde{\pi}$. In the case where producers' welfare peaks first (figure 1A), the consumers' welfare is increasing at E^1 and $\tilde{U}(E^1) > 0$. Thus, figure 1A occurs when $-C_E > 1$ and indicates that the producers and consumers are better off when the amount of public good provided under the producers' control is positive but is smaller than the social optimum. Figure 1B corresponds to the case whereby $-C_E < 1$ at E^1. Here, the social welfare curve peaks before the producers' welfare curve ($E^1 > E^*$). In such cases, consumers' welfare under producers' control of the public good provision may be larger (as depicted here) or smaller than under competition with no public good provision. Figure 1B also suggests that in this case both the producers' and consumers' welfare improves when consumers control the public good provision.

Because the price-reduction effect embodies the impact of the values of η^D, η^S, and ε^q, the cost-reducing effect is, in essence, a measure of the productivity of the public good. Therefore, the scenarios developed above can be linked to different orders of magnitude of demand elasticity and public good productivity given η^S and

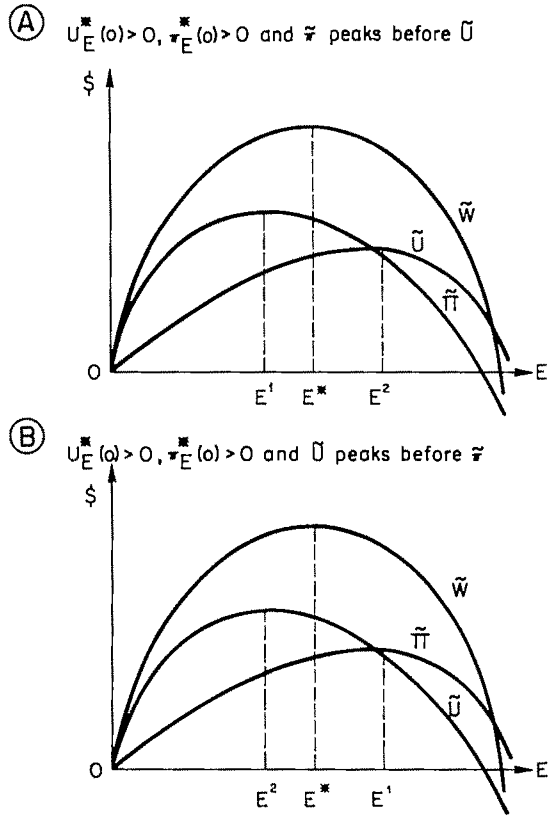

Figure 1. Welfare effects of cost-reducing public good expenditures financed by consumers

ε^q. If public good productivity is sufficiently high and demand elasticity is sufficiently low, a situation may arise where both consumers and producers benefit from the introduction of the public good. One such situation is figure 1A, where the producers' optimum of public good levels is smaller than the social optimum.

Figure 1 sheds some light on the tendency to underinvest in public R&D in U.S. agriculture. Because the demand elasticity for agricultural products is notoriously low and the productivity of public R&D is high (Schultz), the tendency to underinvest in public agricultural R&D is consistent under these conditions with figure 1A. That suggests that the control of R&D in agriculture may have been strongly influenced by producers. Moreover, figure 1A suggests that, under such a scenario, consumers benefit relative to no intervention; therefore, they should not strongly oppose the producers' control over the quantity of the cost-reducing public good, albeit a suboptimal quantity.

Producers' Finance and Determine Public Good Expenditures

Let $\hat{E}$ denote the public good expenditure in thi case. It is nonnegative and maximizes produc ers' welfare for $\alpha = 0$. Using (4), the margina impact of an increase in public good expendi tures on producers' profit is the difference be tween the cost-reducing effect and the sum o the price-reducing effect and the marginal in crease in expenditure. That is,

$$(8) \qquad \pi_E^* = -C_E + q^* p_E^* - 1 = -C_E\left[1 - \frac{\varepsilon^q}{1 - \eta^D/\eta^S}\right] - 1.$$

The optimal level is determined where the sun of the marginal price-reduction effect and th marginal expenditure is equal to the margina cost-reduction effect. It follows that the publi good expenditures increase as the elasticity o demand is increasing (in absolute value), th elasticity of supply is decreasing, and the outpu elasticity of the marginal impact of the publi good on cost is declining.

Comparing equations (5), (6), and (8), whe producers both pay and control the quantity pro vided, the level of public good cannot excee the social optimum or the producers' optimun of the public good when consumers pay. Indeed, the likelihood of no public good bein provided is now greater when producers both fi nance and control the public good compared t either of the two situations discussed earlier There is no possibility of an oversupply of th public good when the producers pay; at most the producers' optimum (when producers pay can equal the social optimum. The equality o positive $\hat{E}$ and E^* occurs when demand is in finitely elastic, supply is completely inelastic or the public good has no effect on variable cost In any of these cases, the producers' optimun when consumers pay will be higher than the so cial optimum.

Therefore, social welfare will increase (com pared to no intervention) if producers both fi nance and control the level of the public goo investment. Moreover, the consumer can onl benefit from positive levels of the public goo when producers control and pay for it. Thus, i seems socially desirable not to prevent collusio among or collective action by firms in a com petitive industry to provide a cost-reducing pub lic good input.

It is inevitable, however, that the resulting leve of the public good investment is less than th

social optimum, with this divergence being greater in sectors with more inelastic demand curves and more elastic supply curves. Hence, it is not sufficient that a social optimum will be obtained if the government encourages firms to provide the public good themselves by collusive agreements. Indeed, the government would have to intervene and supplement the private levels of cost-reducing input and even more so with higher supply elasticities or lower demand elasticities. This may lead to a crowding out of private investment, so that governments would always have to provide or control directly the total expenditure on cost-reducing public good inputs in order for a social optimum to be attained.

Policy Implications and Concluding Remarks

Historically, government has provided and financed a large part of the public good inputs used in U.S. agriculture. Research and development, water projects, information, extension services, and regional pesticide control are examples. Despite the consensus that agricultural research has been a highly productive form of public investment from a social perspective, there is overwhelming empirical evidence of underinvestment in this research. Moreover, patterns of funding and rates of return from research vary substantially among commodities. The foregoing analysis emphasizes two elements in explaining and prescribing the level of public good inputs in agriculture: the distribution of political influence and the economic properties of the markets involved. It focused on cases where the provision of public good inputs improves the welfare of both producers and consumers (relative to no provision) and thus constitutes a Pareto improvement.

The first institutional arrangement considered is the provision of public good inputs by consumer (taxpayer) financing, which characterizes most research and extension activities in U.S. agriculture. If producers control the level of public good provided and the quantity is smaller than the social optimum, then all groups gain relative to no public good provision. Furthermore, it was found that with inelastic demand and a very productive public good, characteristics historically attributed to U.S. agriculture, there would be a large gap between the producer and social optimum. This may partially explain the tendency for significant underinvestment in public R&D in agriculture.

A second institutional arrangement analyzed is when producers organize to provide the public good themselves. Examples include specialty crop research financed by funds raised through marketing orders, institutional arrangements such as water districts which construct and manage water usage, and pesticide control districts financed by producers. In these cases, consumers always gain, but less public goods are provided than is socially optimal. Moreover, a smaller amount of the public good is provided when producers both finance and control its level compared to situations of taxpayers financing and producers determining its level. This may explain situations whereby producers lobby for the construction of new water transfer or disposal facilities with public monies while refusing or failing to finance such projects themselves when public support is denied. In situations where producers finance an undersupply of the public good, governments may be tempted to augment public provision of the public good inputs. Such augmentation confronts the risk of curtailing the private provision of the public good input and substituting public for private financing which, unless government provides the socially optimal quantity, will still result in an undersupply.

The elasticities of supply and demand determine the deviation of alternative policy interventions from the zero quantity outcome. Elasticities also affect the distribution of welfare between groups under alternative cost-sharing arrangements. One plausible hypothesis in explaining the historical provision of public goods in agriculture is that producers introduce and promote public good policy intervention to which consumers do not object as long as the latter's welfare is improved (compared to no intervention). Thus, if the demand elasticities are low, there is positive public research at the producer optimum and, at this level, consumers are better off relative to no public good. If the demand elasticity for a commodity is high, then producers would tend to finance and provide public goods themselves because consumers would otherwise lose welfare. This perhaps explains the evidence in studies by Ruttan; and Judd, Boyce, and Evenson, that public research expenditures for major field crops are underfunded relative to livestock products. On the other hand, research on some specialty crops does not receive public funding at all and is supported only by growers' funding obtained through marketing orders. Heuristically, it seems that specialty crops have higher elasticity of demand than livestock products which, in turn, have higher

demand elasticities than field crops.

Our analysis implies that the demand elasticities of specialty crops are high enough that taxpayer-funded research will reduce consumers' welfare. Therefore, there is no support for publicly funded research, and producers must provide it themselves. Elasticities of demand for field crops and livestock may be low enough that consumers' welfare increases with public financing of R&D. If producers control the level of public research whenever it is provided, then they would prefer relatively more research in livestock products (with higher demand elasticities) than in field-crop products.

The analysis in this paper also helps to explain the basic patterns of support of water projects. We observe taxpayers paying for large projects (e.g., the California Central Valley and Federal water projects) which support an industry large enough to face an inelastic demand for the product grown (e.g., the cotton industry in central California). Regional water projects, on the other hand, involve small numbers of farmers such that the demand elasticity for their output is relatively elastic compared to that facing all farmers in the sector. Hence, projects in local water districts are typically controlled and financed by producers.

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A Game-Theoretic Model of Endogenous Public Policies

John C. Beghin

Public policies are the equilibrium outcome of a cooperative game among interest groups and the policy maker. This study stresses the interdependence between policies and players' bargaining strengths and derives their comparative statics with respect to a changing economic environment. It also provides a specification of behavioral equations consistent with the underlying bargaining process. An analysis of the political economy of food and agricultural price policies in Senegal illustrates the proposed framework.

Key words: bargaining game, endogenous policies, interest group.

Endogenous public policy is a familiar concept in the agricultural economics literature. Rausser and Stonehouse, and Abbott (1979a) have formulated and estimated policy behavioral equations to analyze changes in policy decisions in response to exogenous shocks. Abbott assumes that domestic price and import policies are influenced by international variables (e.g., world prices, foreign exchange reserves). Rausser and Stonehouse explain policy instruments by variables representing the interest of pressure groups. These policy behavioral equations are essentially partial reduced forms; no structural identification is claimed.

The revealed preference approach (Rausser and Freebairn, Sarris and Freebairn, Paarlberg and Abbott) explicitly acknowledges the influence of pressure groups in the policy process. The policy maker maximizes a weighted objective function reflecting the welfare of lobbying groups and reveals his preferences through the weights he attributes to the different objectives. This approach has been successful in explaining agricultural policies; however, it does not provide a formal structure of the political economy underlying the objective function of the policy maker.

Cooperative game theory provides a formal model of the bargaining process among lobbying groups and the policy maker that leads to the criterion function of revealed preference (Harsanyi 1963, Zusman). This framework has been applied to the political economy of food price policies in Israel (Zusman and Amiad) and Senegal (Beghin and Karp). Rausser, Lichtenberg, and Lattimore summarize these three approaches.

This paper provides a game-theoretic model of public policy formation that determines simultaneously the endogenous policies and bargaining strength and welfare of the interest groups involved. The economic environment (e.g., world prices, fixed inputs) changes and alters the solution of the game, the equilibrium policies, and distribution of bargaining power among players. The purpose of the paper is to explain and predict endogenous policy changes caused by shifts in the bargaining process underlying the policy formation.

The model provides an original way to quantify and predict endogenous policy changes induced by exogenous shocks without resorting to the econometric estimation of behavioral equations. The framework incorporates the structure of the political economy of public policies that is missing in the behavioral equation approach. Signs and magnitudes of the influence of the exogenous shifters on the policies are computed based solely on information yielded by the estimated game. Previous research on endogenous policies assumed fixed weights in the objective function and did not link shocks of the bargaining process underlying policies to changes in these policies. The approach followed in the study makes that link explicit and uses it to predict policy changes.

The derivation of the comparative statics of

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policy responses also indicates which exogenous variables should be included in the specification of behavioral equations. The suggested specification is entirely consistent with a clearly defined bargaining process among interest groups. Comparison of the two sets of estimated multipliers gives complementary insights and an informal check of the validity of the methodology.[1]

The approach is applied to food and agricultural price policy changes in Senegal. Urban dwellers consuming imported cereals, groundnut farmers, and a marketing board with market power are involved in a game to determine consumer prices of cereal imports and producer prices for groundnuts and agricultural inputs. The influences of world prices, the exchange rate, and some other shocks on the bargaining process and on price policies are estimated. The empirical illustration is interesting because the framework rationalizes the adoption of hybrid policies by African governments which resist recommendations from donor institutions to remove distortions (Scandizzo and Bruce). However, the approach is not restricted to developing countries; it is applicable to many other types of contractual agreements and negotiated policies (e.g., European Community—EC—farm policies, tobacco producer prices in Australia, and wage/employment contracts in labor/management bargaining).

The game-theoretic framework is presented in the next section with emphasis on the complementarity of revealed preference and cooperative game theory. The comparative statics of the equilibrium strategies (i.e., the policy instruments) are derived with respect to changes in the predetermined economic environment, and a proper specification for policy behavioral equations is suggested. Then, the framework is applied to the Senegalese case, the gaming situation is econometrically estimated, and the implications of the results are considered.

A Cooperative Game Framework

The bargaining process between pressure groups and the policy maker often leads to enforceable agreements among the players, making plausible the use of cooperative game solutions (Shubik). From the possible solution concepts, the reference point solution is chosen for use in th study (Thomson 1981). Reference points ar payoffs players refer to when they evaluate pay off proposals. The Nash conflict point, d, an the point of minimum expectation, mex, are ex amples of reference payoffs. They are shown i figure 1, for a two-player game, with their co responding solutions u_d^* and u_{mex}^* on the frontie H, of the payoff set, P. Any convex combina tion of these two reference points can be anothe reference point with its solution on the frontie between u_d^* and u_{mex}^*. Once the conflict point i known, the original Nash solution is unique whereas many reference point solutions are pos sible. Thus, fewer solution candidates are ex cluded a priori from being the equilibrium so lution. The latter approach avoids imposin unnecessary rigidity on the model. It is also as sumed that the payoff set and its frontier chang with the economic environment. Hence players payoffs, their bargaining powers, and equilib rium strategies are influenced by exogenou shocks (e.g., world prices and exchange rate)

Friedman, and Thomson (1981) present th axioms characterizing the reference point solu tion as a generalization of the Nash axioms.[2] the reference point meets some regularity co ditions (Thomson 1981), a solution that satisfie the four axioms maximizes the modified Nas product, i.e., the product of players' gains fro reaching an agreement,

$$(1) \qquad \prod_{i=1}^{n} (CV(s(z), z)_i - g(P, d)_i),$$

where $CV = (CV_1, CV_2, \ldots, CV_n)$ is the vect of utilities of payoffs of the n players and be longs to the utility set $P(z)$; $g(P, d)$ is the re erence point of the players; variable s is the vec tor of strategies available to the players; and is the vector of exogenous variables displacin the game.

For P convex and compact, the solution CV satisfies the necessary and sufficient condition

$$(2) \qquad H(CV_1^*, CV_2^*, \ldots, CV_n^*, z) = 0, \text{ and}$$

$$(3) \qquad a(z)_i(CV(s(z), z)^* i - g(P, d)_i) = a(z)_j(CV(s(z), z)^* j - g(P, d)_j) \text{ for all } i,$$

[1] In the attempt to unify the policy behavioral equation methodology and the revealed preference-game theory approaches, we voluntarily omit the imperfect world market aspects of Sarris and Freebairn and others. World prices are assumed given in this approach.

[2] The axiom of joint efficiency requires that the solution, CV lies on the upper boundary, H, of the payoff space. The axiom linear invariance states that the solution to the game obtained by positive affine transformation of players' utility function is the po itive affine transformation of the solution to the original game. T axiom of symmetry insures that indistinguishable players recei the same payoff. The independence of irrelevant alternatives axio says that excluding a point from P, other than the solution or re erence point, does not change the solution to the game.

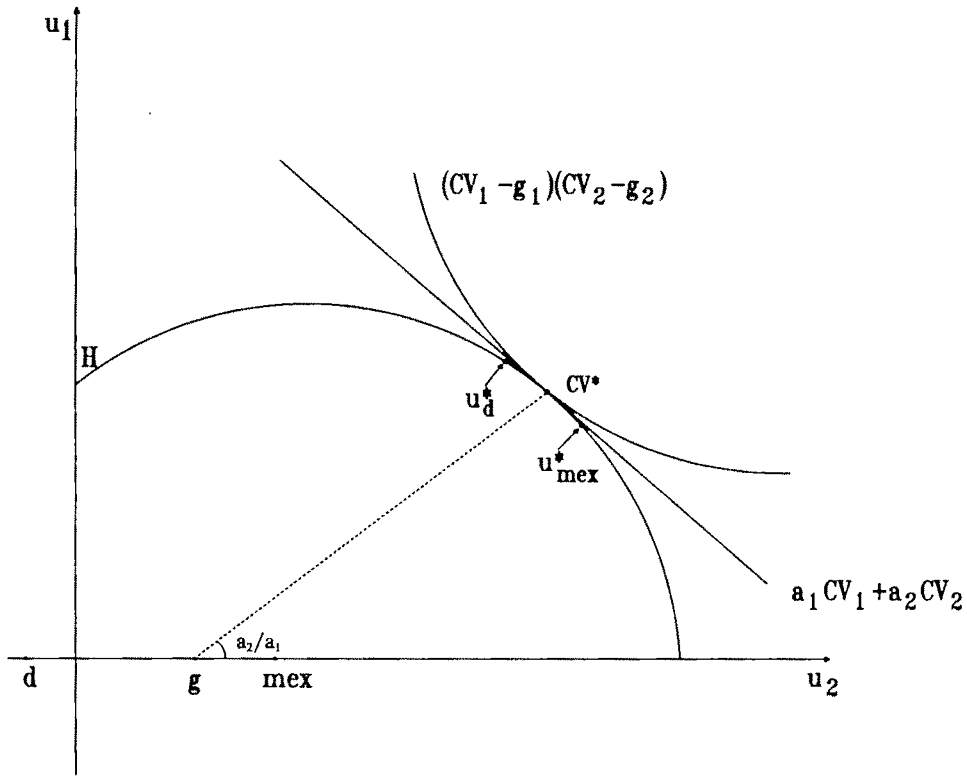

Figure 1. A two-person cooperative game

where $a(z)_i = \partial H(CV^*, z)/\partial CV_i$. The $a(z)_i$'s represent the bargaining-power coefficients of the players; they are the weights of the objective function of revealed preference. And H is the implicit function describing the frontier of the payoff set P. Equation (2) insures that the solution is on the frontier of the payoff set. According to (3), players with prospects of high utility gains have less bargaining power than players with small potential gains from reaching an agreement.

Maximizing (1) is equivalent to maximizing the weighted sum of utilities W:

$$(4)\qquad W = a(z)_1CV(s(z), z)_1 + a(z)_2CV(s(z), z)_2 + \dots + a(z)_nCV(s(z), z)_n.$$

Equation (4) represents the objective function of revealed preference, showing the relative importance of players' utilities. Optimum strategies maximize (4) [or equivalently (1)]. The first-order conditions are

$$(5)\qquad \sum_{i=1}^{n} a(z)_i \frac{\partial CV(s(z), z)_i}{\partial s(z)_k} = 0 \text{ for } k = 1, \dots, t.$$

Figure 1 illustrates equations (1) to (5). The Nash product (1) is the rectangle hyperbola tangent to the frontier H at the solution, CV^*. Conditions (2) and (3) determine the equilibrium solution on the frontier. Player 1 has more bargaining power than his opponent, as indicated by the slope coefficient a_2/a_1 smaller than unity. Moving g to the right horizontally would increase player two's strength and payoff, CV_2. At CV^* the hyperplane tangent to both the payoff set and Nash product is the objective function of revealed preference. First-order conditions (5) push the welfare function outward to the solution tangency point. The convexity of P insures that (2), (3), and (5) are sufficient conditions.

Optimum strategies (policies) are solutions of (5). In general, it is not possible to solve (5) for an expression giving equilibrium strategies as functions of exogenous variables. To derive the comparative statics of the equilibrium strategies with respect to exogenous shocks, the envelope theorem is applied to (5),

(6)
$$\sum_{i=1}^{n}\left[\frac{\partial CV_i}{\partial s_k}\frac{da_i}{dz_j} + a_i\frac{\partial^2 CV_i}{\partial s_k \partial s}\frac{ds}{dz_j} + a_i\frac{\partial^2 CV_i}{\partial s_k\,\partial z_j}\right] = 0;$$

where z_j refers to the jth shock; $\partial^2 CV_i/\partial s_k \partial s$ is the vector of derivatives of $\partial CV_i/\partial s_k$ with respect to s; the scalar $\partial^2 CV_i/\partial s_k \partial z_j$ is the cross derivative of CV_i with respect to s_k and z_j; and the vector ds/dz_j gives the response of the equilibrium strategies s (i.e., the policy variables) to changes in z_j. There are tm equations (6), for t strategies and m shocks. The system of equations for a given shock z_j is

(7)
$$\sum_{i=1}^{n} \left[\frac{da_i}{dz_j} \frac{\partial CV_i}{\partial s'} + a_i \frac{\partial^2 CV_i}{\partial s' \partial s} \frac{ds}{dz_j} + a_i \frac{\partial^2 CV_i}{\partial s' \partial z_j} \right] = 0.$$

Equation (7) is solved for the vector ds/dz_j:

$$(8) \quad \frac{ds}{dz_j} = - \left[\sum_{i=1}^{n} a_i \frac{\partial^2 CV_i}{\partial s' \partial s} \right]^{-1} \cdot \left[\sum_{i=1}^{n} \left[\frac{\partial CV_i}{\partial s'} \frac{da}{dz_j} + a_i \frac{\partial^2 CV_i}{\partial s' \partial z_j} \right] \right] \quad \text{for } j = 1, \ldots, m.$$

The right-hand side of (8) shows the effects of the shock on the bargaining power structure and on the derivatives of the utility functions. The first effect is da/dz_j or $\partial(\partial H/\partial CV)/\partial z_j$; the second one is $\partial(\partial CV/\partial s)/\partial z_j$. The sign of the multipliers ds/dz_j is analytically ambiguous. The multipliers ds/dz_j are computable once estimates of $\partial CV_i/\partial s'$, $\partial^2 CV_i/\partial s' \partial s$, $\partial^2 CV_i/\partial s' \partial z_j$, and da/dz_j are available.

Based on ds_k/dz, a linear approximation of the function relating the kth policy to the shocks, $s_k = f(z)$, is

$$(9) \quad s_k \approx (df(z)/dz)' z + s_k^0 = \beta' z + s_k^0;$$

where s_k^0 is a constant term and β is the vector of multipliers ds_k/dz. Since the multipliers ds/dz are themselves functions of the shocks z, a linear specification of (9) implies an approximation. With an additive error term, (9) provides a specification for the eventual estimation of linear behavioral equations consistent with the bargaining process described by (1) to (5); the multipliers ds_k/dz are the regression coefficients in this case.

The Senegalese Application

The application concerns the political economy of food and agricultural prices in Senegal for the period 1960 to 1980, a period of stability and continuity in institutions and policies. Pressured by international donors, the Senegalese government undertook profound structural reforms i[n] the early 1980s that considerably disrupted pol[-]icies and institutions. Senegalese agricultural an[d] food policies are the outcomes of a bargainin[g] process among economic groups and the gov[-]ernment. Commodity taxation and institution[-]alized market power are the main policy tool[s] to generate and transfer rent from the rural sec[-]tor to government bureaucracies and urban con[-]sumers.

The Senegalese game contains three players[:] farmers in the groundnuts basin growing ground[-]nuts and millet, urban dwellers consuming ric[e] and wheat products, and government agencie[s] determining food and agricultural price policie[s] (hereafter called the marketing board).

Groundnuts is the major cash crop of Sene[-]gal. Since the early 1960s, farmers have bee[n] organized into cooperatives that are unionize[d] and represented in several important state agen[-]cies involved in groundnuts marketing. After in[-]dependence in 1960, small, private groundnut[s] traders were rapidly replaced by a national mar[-]keting board, which has had monopsony powe[r] over groundnuts production since 1964. Farm[-]ers sold their production to the marketing boar[d] through the cooperative. In 1980, the marketin[g] board was dissolved by France as a condition t[o] providing more financial assistance to Senegal[.]

Since 1962, official prices have been an[-]nounced to the farmers before the planting sea[-]son by the marketing board. The prices are es[-]tablished by the Comité des Grands Produits, a[n] interministerial government committee whe[re] cooperatives are present. The political influenc[e] of religious leaders (*marabouts*) is another im[-]portant element in the policy process. The po[-]litical stability in rural areas relies on the he[-]gemony of Moslem leaders who are importan[t] groundnuts producers. Their presence essen[-]tially puts a lower bound on the groundnuts of[-]ficial producer price. This producer price has bee[n] below world price but higher than the level cor[-]responding to full monopsony power. If pro[-]ducer prices are too unfavorable, farmers ca[n] retaliate by changing their crop patterns, smug[-]gling cash crops to bordering countries, default[-]ing on input loans, and withdrawing their po[-]litical support.

Millet is a nontraded rural staple that is pro[-]duced by the same farmers producing ground[-]nuts. Millet and groundnuts compete for the sam[e] inputs. The marketing board was only margin[-]ally involved in millet marketing. Nevertheless[,] millet production and consumption are influ[-]enced by groundnuts and fertilizer-related poli

cies. Millet-market quantity and price are endogenously determined once the fertilizer and groundnuts prices are known.

From 1964 to 1980, a credit system allowed the members of agricultural cooperatives to buy fertilizer and equipment at subsidized prices. The Senegalese government hoped that the subsidized inputs would compensate for the negative impact of low groundnut producer price. The marketing board was in charge of the delivery of the inputs. At the start of the marketing season, the farmers paid back the loans with groundnuts sales. The credit system was abolished in 1980 with the dissolution of the marketing board.

Rice is the major imported cereal and urban staple. An agency closely related to the marketing board (Caisse des perréquation et de stabilization de prix) has had a monopoly for this market. The retail price is fixed by law. It is usually set above the import cost, but the tariff has been moderate. The retail price has been subsidized when world prices increase unexpectedly. These increases in world prices have been transmitted to consumers over a period of time.

Senegal does not produce any wheat, and its import decisions are made by the marketing board. Wheat is milled and transformed into bread for consumption in urban areas. Prices are regulated by the government. Millers have been subsidized to sell the flour below cost to bakers. The retail price of bread is fixed by law at a very low level. In case of high cereal consumer prices, urban dwellers can create political agitation, weaken the legitimacy of the political decision maker, and vote against him. As in many developing countries, the threat of urban unrest is a strong deterrent against high food prices in Senegal (Bates, p. 33).

The Empirical Model

The indirect utility of the representative farmer, U_1, is

$$(10)\quad U_1 = U_1(P_m, P_{-m}, m_1(P_g, P_m, P_f, z_1) - C_1),$$

where P_m, P_{-m}, P_g, and P_f are the price of millet, price vector for consumption goods other than millet, producer price of groundnuts, and fertilizer, respectively. The variable z_1, a subset of z, expresses the influence of some of the exogenous variables on the restricted profit function (i.e., rural labor, land, and rainfall). The restricted profit function m_1 minus the cost of implementing conflict strategies, C_1, represents the farmer's net income.[3] At the cooperative solution, C_1 is equal to zero because conflict strategies are not used. By Hotelling's lemma, the supplies of groundnuts and millet, q_g^s and q_m^s, and the demand for fertilizer, q_f^d, are derived. The farmer markets his whole groundnut production. Roy's identity gives the farmer's demand for millet, q_m^d.

The farmer's payoff function is defined as the negative of the compensating variation for changes in prices and income,[4]

$$(11)\quad CV_1 = -[e_1(P_m, P_{-m}^0\, U_1^0,) - e_1(P_m^0, P_{-m}^0\, U_1^0) - m_1(P_g, P_m, P_f, z_1) + m_1^0\,(P_g^0, P_m^0, P_r^0, z_1)];$$

where m_1 and P_m refer to the current period, and m_1^0 and P_m^0 are their counterparts in the starting period, 1960; e_1 is the expenditure function of the farmer. Changes in the price P_{-m} are not considered, and compensating variation and millet demand are assumed to depend only on millet price and income. Millet supply and demand must be equal at the market equilibrium because millet is a nontraded commodity. Each farmer takes prices as given, but at the market level changes in the groundnuts and fertilizer prices affect the price of millet. Computation of the derivatives of the payoff functions with respect to price policies includes these general equilibrium effects.

A typical urban consumer has an indirect utility function U_2, with consumption prices and income as arguments:

$$(12)\quad U_2 = U_2(P_r, P_w, P[-r, -w], m_2 - C_2),$$

where P_r, P_w, $P[-r, -w]$ are the prices of rice, wheat products, and other goods, respectively. Income of the urban consumer is equal to the exogenous wage income m_2 minus the cost of applying conflict strategies C_2 (e.g., cost of rioting or striking). At the cooperative equilibrium, C_2 is equal to zero because of the absence of conflict. Roy's identity gives cereal demands q_r^d and q_w^d, which are assumed to be functions of rice and wheat consumer prices and of income. The urban consumer's payoff function is the

[3] The variable C_1 could be modified to include the cost of influencing the policy maker during the bargaining process (e.g., PAC contributions).

[4] Compensating variation, with equivalent variation, are standard measures of utility differences. They are money metric utility functions or compensation functions expressing the necessary dollar amount to offset a welfare change induced by changes in prices and income. They are linear in dollars and satisfy the axiom of linear invariance.

negative of the compensating variation for changes in P_w, P_r, and m_2:

$$(13) \quad CV_2 = -(e_2(P_r, P_w, P^0[-r, -w], U_2^0) - e_2(P_r^0, P_w^0, P^0[-r, -w], U_2^0) - m_2 + m_2^0),$$

with the superscript 0 denoting 1960 and e_2 representing the expenditure function of the urban consumer.

The marketing board chooses price variables P_g, P_f, P_r, and P_w to maximize the sum of net tax revenues in the four markets. This assumption is not very restrictive because the allocation of surplus generated through taxes is not specified. Under this assumption the marketing board can extract or transfer surplus depending on players' bargaining strength. The tax revenue function TR is

$$(14) \quad TR = (WP_g - P_g)q_g^s + (P_f - WP_f)q_f^d + (P_r - WP_r)q_r^d + (P_w - WP_w)q_w^d - D_1 - D_2,$$

where WP_g, WP_r, WP_w are the world prices of groundnuts, rice, and wheat, and WP_f is the ex-factory price of fertilizer. All these prices are exogenous; the world prices are multiplied by the nominal exchange rate and expressed in CFA francs. The nominal exchange rate (cost of dollars in CFA francs) is also exogenous. Variables D_1 and D_2 represent the cost to the marketing board of being in conflict with farmers and urban dwellers. The payoff function of the marketing board, CV_3, is the change in tax revenues when prices move from the starting to the current level,[5]

$$(15) \quad CV_3 = TR(P_g, P_f, P_r, P_w) - TR(P_g^0, P_f^0, P_r^0, P_w^0).$$

Equations (3) and (5) are applied to the Senegalese case. The strategies of the marketing board are the four price policies P_g, P_f, P_r, and P_w. Farmers and urban dwellers have political strategies that, although not observed, influence the marketing board in its pricing decisions. The optimum political pressure exerted by these two players on the policy maker satisfies conditior (5). Recall that farmers can smuggle their cash crop, default on loans, or withdraw their support to the existing political system; urban consumers can riot, go on strike, shirk, and vote against the elected policy maker.

The first-order conditions to maximize the welfare function W are

$$(16) \quad a(z)_1 \left(\frac{dCV_1}{dP_i}\right) + a(z)_3 \left(\frac{dCV_3}{dP_i}\right) = 0, \quad \text{for } i = g, f; \text{ and}$$

$$(17) \quad a(z)_2 \left(\frac{\partial CV_2}{\partial P_k}\right) + a(z)_3 \left(\frac{\partial CV_3}{\partial P_k}\right) = 0, \quad \text{for } k = r, w.$$

Total derivatives are taken in equation (16) to account for the intermarket relationships between millet, and groundnuts and fertilizer markets. Millet is a nontraded good whose market equilibrium is displaced by changes in policies P_g and P_f. The total derivatives dCV_j/dP_i in (16) are the sum of the direct effect, $\partial CV_j/\partial P_i$, and indirect effect via the millet price, $(\partial CV_j/\partial P_m)\cdot(dP_m/dP_i)$.

Before estimating (3), (16), and (17), we must specify the influence of z on the bargaining power coefficients. This step is necessary to recover the coefficients $a(z)_i$'s and their derivatives da_i/dz. The ratios of bargaining coefficients are approximated as linear functions of exogenous variables,

$$(18) \quad \frac{a_2(z)}{a_3(z)} = a_{23} + a_{231}WP_g, \text{ and}$$

$$(19) \quad \frac{a_3(z)}{a_1(z)} = a_{31} + a_{311}WP_r + a_{312}dol + a_{313}pop$$

where pop is the total population of Senegal, and dol is the exchange rate. Attempts to include the other exogenous variables of the model (land, rainfall, per capita income of the urban consumer, world price of wheat, and ex-factory price of fertilizer) into the ratios (a_i/a_j) proved unsuccessful.

The bargaining coefficients and their derivatives are recovered as follows. First, the bargaining coefficients are normalized to sum to one. The normalization, (18) and (19), are solved for the three coefficients,

$$(20) \quad a(z)_1 = \frac{1}{(1 + (1 + a_{23} + a_{231}WP_g)(a_{31} + a_{311}WP_r + a_{312}dol + a_{313}pop))},$$

[5] Other definitions of the utility function CV_3 were tried. When we assume an altruistic marketing board caring about both tax revenues and the income distribution between the urban and farm sectors, we obtain nonsensical results. We do not find evidence showing that the marketing board cares about the welfare of the other players outside of the bargaining process.

$$a(z)_2 = \frac{(a_{23} + a_{231}WP_g)(a_{31} + a_{311}WP_r + a_{312}dol + a_{313}pop)}{(1 + (1 + a_{23} + a_{231}WP_g)(a_{31} + a_{311}WP_r + a_{312}dol + a_{313}pop))}, \text{ and} \tag{21}$$

$$a(z)_3 = \frac{(a_{31} + a_{311}WP_r + a_{312}dol + a_{313}pop)}{(1 + (1 + a_{23} + a_{231}WP_g)(a_{31} + a_{311}WP_r + a_{312}dol + a_{313}pop)).} \tag{22}$$

Then the derivatives da_i/dz_k are computed taking into account that $\Sigma_{i=1}^{n} da_i/dz_k = 0$. Even if a specific exogenous variable enters only one equation, (18) or (19), it influences the whole bargaining-power structure via normalization of the a's. Equations (18) and (19) are substituted into (3), (16), and (17) to form the system

$$CV_3 = (a_{23} + a_{231}WP_g)(CV_2 + b_{23}), \tag{23}$$

$$CV_1 = (a_{31} + a_{311}WP_r + a_{312}dol + a_{313}pop)(CV_3 + b_{31}), \tag{24}$$

$$\frac{\partial CV_3}{\partial P_i} = -(a_{23} + a_{231}WP_g)\frac{\partial CV_2}{\partial P_i}, \text{ for } i = r, w; \text{ and} \tag{25}$$

$$\frac{dCV_1}{dp_k} = -(a_{31} + a_{311}WP_r + a_{312}dol + a_{313}pop)\frac{dCV_3}{dp_k}, \text{ for } k = g, f. \tag{26}$$

Equations (23)–(26) are estimated with time-series data from 1960 to 1980. The estimation is organized in two steps. First, supply and demand equations are estimated to generate measurements of the payoff functions and their derivatives. Then the game is estimated.

Assuming millet expenditure is linear in millet price and farm income, the estimated millet demand yields the parameters necessary to compute the farmer's compensating variation. The estimated groundnut and millet supplies are linear in relative prices, P_g/P_f and P_m/P_f, and give the profit function's parameters needed to compute the derivatives of the farmer's compensating variation and tax-revenue function with respect to P_g and P_f.

No simple well-behaved functional form could fit the urban consumption data. The sum of changes in consumer surplus in the rice and wheat markets and changes in income approximates the urban consumer's compensating variation. A double logarithmic specification expresses cereal urban demands as functions of the two cereal prices, income and time trend. The estimated urban consumption parameters are used to compute the derivatives of the urban consumer's and marketing board's payoff functions with respect to P_r and P_w. This first step of the estimation and the data are reported in an appendix, available upon request from the author.

Because the payoff functions and their derivatives are endogenous variables, an instrumental variable technique is required. The payoff functions and their derivatives are the equilibrium outcome of the game; hence, they are simultaneously determined. Thus, iterative two-stage least squares is used. The parameter estimates are shown in table 1, with the bargaining-power coefficients implied by these estimates. At the sample mean the bargaining coefficient estimates are $a_1 = .5906$, $a_2 = .1351$, $a_3 = .2743$, respectively, for the farmer, urban consumer, and marketing board. The larger magnitude of a_1 is unexpected because of the price policies favoring urban consumers and the marketing board. It is explained as follows. Farmers' reference point is closer to their optimum payoff than are those of the urban consumers and the marketing board. In case of conflict, farmers have their subsistence crop as an alternative; conversely, the marketing board and urban consumers have more to lose in a disagreement. They will be much worse off because their reference points are further away from the optimum solution and this weakens their bargaining strength (Thomson 1987).[6]

The derivatives of the coefficients a_i's with respect to the four exogenous variables are calculated at the mean with the regression estimates and are also reported in table 1. The farmers and the marketing board enhance their bargaining positions with a higher world price of groundnuts. More expensive rice imports disadvantage urban consumers and the marketing board relative to the farmers. Less intuitive directions are obtained for the other two exoge-

[6] Possible misspecification of the payoff functions of the players could also bias the a's estimates.

Table 1. Estimation of the Game with Iterative Two-Stage Least Squares

Parameter	Estimate	Std. Error	Asymptotic T-Ratio
a_{312}	0.01089	0.0024	4.39
a_{313}	1.76E-07	6.99E-08	2.52
a_{311}	−2.00E-05	2.98E-06	−6.71
b_{31}	−70.34579	30.69248	−2.29
a_{31}	−2.45668	0.78836	−3.12
a_{23}	1.28022	0.23308	5.45
a_{231}	−1.75E-05	3.94E-06	−4.44
b_{23}	−158.24	43.2921	−3.66

Predicted Bargaining Coefficients and Their Derivatives

Variable	Mean
$\partial a_1/\partial WP_g$	0.00068922
$\partial a_1/\alpha WP_r$	0.00253108
$\partial a_1/\partial pop$	−0.00000009
$\partial a_1/\partial dol$	−0.00404860
$\partial a_2/\partial WP_g$	−0.00100930
$\partial a_2/\partial WP_r$	−0.00083520
$\partial a_2/\partial pop$	0.00000003
$\partial a_2/\partial dol$	0.00073186
$\partial a_3/\partial WP_g$	0.00032008
$\partial a_3/\partial WP_r$	−0.00169590
$\partial a_3/\partial pop$	0.00000006
$\partial a_3/\partial dol$	0.00330874
a_1	0.590622
a_2	0.135086
a_3	0.274292

nous variables. Population and exchange rate influence positively the bargaining position of urban consumers and the marketing board to the disadvantage of farmers.

With estimates of da/dz, $\partial CV_i/\partial s'$, $\partial^2 CV_i/\partial s'\partial s$, and $\partial^2 CV_i/\partial s'\partial z_j$, the multipliers, ds_k/dz_j, are computed as in (8). Seven possible shocks are considered: changes in the world price of groundnuts, wheat, and rice, WP_g, WP_w, WP_r; in the exchange rate, dol; in the ex-factory price of fertilizer, WP_f; in population, pop; and in the income of urban consumers, m_2. The multipliers ds/dz_j are presented in table 2 in elasticity form $(ds/s/dz_j/z_j)$. The groundnut producer price is negatively related to most variables except the world price of groundnuts. The fertilizer prc ducer price decreases with higher world price of groundnuts and rice and increases with risin population, exchange rate, and ex-factory pric of fertilizer. The rice consumer price is nega tively influenced by a rise in world cereal price and urban income. Opposite effects are obtaine for the world price of groundnuts, populatior and exchange rate. Higher urban income, por ulation, and world price of rice induce increase in the wheat consumer price; in contrast, ir creases in exchange rate, world prices of whea and groundnuts lower the same consumer price

Estimation of Behavioral Equations

Behavioral equations are also estimated with th time-series data included in the appendix. Th behavioral equations are specified linearly, as i (9), with the shocks considered in the previou section as explanatory variables. This allow comparison of the two approaches for the sam set of exogenous shocks. The equations are

$$(27)\quad P_i = \beta_{i0} + \beta_{i1}WP_g + \beta_{i2}WP_r + \beta_{i3}pop + \beta_{i4}dol + \beta_{i5}WP_f, \text{ for } i = g, f; \text{ an}$$

$$(28)\quad P_k = \beta_{k0} + \beta_{k1}WP_g + \beta_{k2}WP_r + \beta_{k3}pop + \beta_{k4}dol + \beta_{k5}m_2 + \beta_{k6}WP_w, \text{ for } k = r, w$$

Assuming additive error terms that satisfy th Gauss-Markov assumptions, (27) and (28) ar estimated with ordinary least squares, and th results are presented in table 3. Overall, th regressions give good fit (high R^2), although som variables are not statistically significant (low T value). The multipliers ds/dz based on regres sions are presented in elasticity form in table 4

The two approaches give the same impact d rections in more than 75% of the cases, but th magnitudes differ. The game approach tends t

Table 2. Impact of Exogenous Shocks on Price Policies

	Price Policies Groundnuts	Fertilizer	Rice	Wheat
World price of groundnuts	2.333	−0.683	1.073	−2.88
World price of rice	−1.378	−5.272	−0.451	9.37
Population	−1.930	4.082	3.414	14.52
Exchange rate	−1.954	13.169	4.955	23.47
Urban income	0	0	−1.281	1.50
World price of wheat	0	0	−0.144	−6.11
Ex-factory price of fertilizer	−2.531	1.935	0	0

Table 3. Price Policy Behavioral Functions. OLS Regressions

	Groundnut Price	Fertilizer Price	Rice Price	Wheat Price
Intercept	33,275.344	18,120.779	−29,010.569	21,946.423
	(2.851)[a]	(3.040)	(−1.309)	(1.194)
World price of groundnuts	53.852	−.930	7.496	−4.851
	(4.067)	(.138)	(.479)	(−.371)
World price of rice	9.176	−22.072	95.396	37.542
	(.518)	(−2.438)	(3.450)	(1.624)
Population	−.003	−.001	.002	.004
	(−3.420)	(−3.136)	(2.220)	(4.540)
Exchange rate	−42.735	−9.201	21.419	−38.797
	(−1.415)	(−.596)	(.333)	(−.706)
Ex-factory price of fertilizer	−.172	.067		
	(−.964)	(.736)		
Urban income			1.443	.322
			(3.596)	(.961)
World price of wheat			−207.206	−28.367
			(−1.085)	(−.178)
F-test	9.474	5.951	8.081	8.257
R^2	.761	.665	.776	.780
D-W	1.961	2.079	2.489	2.289

[a] Figures in parentheses are T-values.

Table 4. Elasticities Based on Behavioral Equations

	Price Policies			
	Groundnuts	Fertilizer	Rice	Wheat
World price of groundnuts	0.580	−0.020	0.047	−0.021
World price of rice	0.056	−0.273	0.342	0.093
Population	−0.767	0.726	0.377	0.444
Exchange rate	−0.602	−0.262	0.181	−0.221
Urban income	0	0	1.524	0.235
World price of wheat	0	0	−0.485	−0.046
Ex-factory price of fertilizer	−0.199	0.156	0	0

yield larger multipliers. Contradictory results occur for the impacts of the world price of rice on the groundnuts and rice price policies, the influence of the population variable, and exchange rate on the fertilizer price, and the effect of urban income on the rice consumer price.

The game-theoretic approach yields comparative statistical results without considering lags in adjustment of policies to exogenous shocks and in responses of economic agents to policy changes. The introduction of lagged values of z (except population), as additional explanatory variables in (27) and (28), reduces the difference in magnitudes between the two approaches. The results are shown in table 5. Unfortunately, the small size of the data set limits

Table 5. Elasticities with Lagged Variables

	Price Policies			
	Groundnuts	Fertilizer	Rice	Wheat
World price of groundnuts	0.610	−0.484	0.085	−0.017
World price of rice	0.125	−0.359	0.573	0.120
Population	−0.811	−0.340	0.235	0.284
Exchange rate	−0.621	−0.394	−0.341	−0.690
Urban income	0	0	1.635	−0.424
World price of wheat	0	0	−1.067	−0.140
Ex-factory price of fertilizer	−0.299	0.177	0	0

Note: Elasticities include the impact of current and lagged variables (1 period lag).

the number of variables and lag structures that could be incorporated into (27) and (28), and decreases the statistical significance of the estimated regressions. Nevertheless, the contrast between the game theory and reduced-form results is consistent with a long-run/short-run dichotomy. The actual data reflect the dynamics of players' responses, whereas the game approach assumes instantaneous adjustments. The linear specification of the behavioral equations might be another source of discrepancies between the two sets of results. The introduction of higher-order terms would be preferable if sufficient data were available.

Finally, the multipliers derived from the game approach are conditional to the specification chosen for the players' preferences and technology. Potential misspecification of the utility or profit functions could bias the multipliers and explain contradictory results between the two methods.

Concluding Comments

The game-theoretic framework predicted the response of the endogenous public policies to a changing environment. Derivation and quantification of the impact of exogenous shifters on the game equilibrium allowed an estimate of policy responses to those shocks. This approach also provided for the policy behavioral equations, a specification consistent with the bargaining process underlying the policies.

The political economy of food and agricultural prices in Senegal illustrated the proposed approach. The effect of shocks on the price policies was estimated with the bargaining game model and with the behavioral equations. The former computation resulted in larger multipliers than the latter. The Senegalese application therefore suggests that reduced-form multipliers describe short-term responses and raises the issue of appropriate lag structure to capture full adjustment.

As Abbott (1979b) argued, the structural model and reduced-form approach give complementary insights on policies' endogeneity. The behavioral equation approach avoids specification and estimation of players' taste and/or technology parameters; but it offers no insight on the structure of policy decisions, and the linear specification limits the validity of predictions to small shocks. An ad hoc specification can be used if some structural characteristics are known; but the behavioral equation will not correspond to a given structural model, and its coefficien will be difficult to interpret. If short-term pr diction is the main motivation, such ad hc models are appropriate.

The bargaining game framework incorporat agents' behavior and reactions into the polic process. Estimated bargaining weights reveal tl welfare trade-offs made by policy makers in the policy choices. Assumptions about players' b havior, technology, and preferences are nece sary to quantify the game and the policy r sponses to shocks; adding more a priori structu could possibly bias the analysis. This approac also requires a well-documented understandin of the political economy and institutions i volved in policy decisions. As the empirical r sults suggest, game-policy multipliers abstra from the dynamics of adjustment and constitu long-term responses to shocks.

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Some Neglected Social Costs of Government Spending in Farm Programs

Julian M. Alston and Brian H. Hurd

Economic welfare analyses of farm programs typically assume that the direct social opportunity cost of subsidy payments is one dollar per dollar of government spending. Recent literature suggests that the marginal opportunity cost of a dollar of U.S. federal government spending is more likely to be in the range of $1.20 to $1.50. This implies that the net social costs of farm programs that involve government spending are significantly greater than the typical estimates. In addition, the normative efficiency ranking of alternative policies is sensitive to the marginal opportunity cost of government spending.

Key words: deadweight cost of taxes, efficiency of transfers, farm programs.

The economic welfare consequences of U.S. farm programs have been analyzed and measured in a great many studies.[1] Almost all such studies assume that the social opportunity cost of a dollar of government spending is one dollar, and the net social cost of government spending is measured entirely as the indirect cost of the Harberger triangles of distortions in commodity markets induced by the programs. Such an approach does not consider the welfare costs of distortions caused by the collection of taxes elsewhere in the economy to finance government spending in farm programs.

That the opportunity cost of a dollar of government spending is not one dollar is generally well known to economists, certainly among those familiar with the literature on public economics (e.g., Atkinson and Stiglitz, Stiglitz, Harberger) and optimal taxation (e.g., Mirrlees, Sandmo). While the profession has not reached total agreement on the magnitude of this cost, various studies support the view that the margin excess burden of taxation in the United Stat is significant, likely to fall between 20% ai 50%.[2] Thus, the marginal social welfare cost a dollar of government spending (*MWC*) is like to be between $1.20 and $1.50. The implic tions for the social costs and efficiency rankii of farm programs are direct and profound.[3]

In this paper we focus on the implications f the choice of policy instrument. The exact ma nitude of *MWC* is not crucial to the argumer We present a simple diagrammatic, comparati

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[1] Two recent examples are Gardner (1987b) and Council of Economic Advisers. Two early examples are Johnson and Wallace. Most issues of this *Journal* contain at least one instance, as do similar publications.

[2] The literature contains some very wide ranges of estimates, l most studies report a narrower range of preferred estimates. I example, Browning (1987, p. 74) summarized his point of vi as: "The estimates of marginal welfare cost developed here rar from just under 10 percent to just over 300 percent. Extreme (l not impossible) combinations of assumptions about contribut factors are required to generate these polar estimates. My prefer estimates lie in the range of 20 to 50 percent. Several other rec studies have also developed estimates that lie approximately in t range." The other recent studies include, for example, Balla Shoven, and Whalley, who state (p. 128) that "the welfare l from a 1 percent increase in all distortionary taxes is in the rar of 17 to 56 cents per dollar of extra revenue, when we use elastic estimates that we consider to be plausible." See also Browning (19 1987), Stuart, and Findlay and Jones who suggest a range of 2 to 65% for Australia.

[3] For instance, Gardner (1987b) estimated that taxpayer costs farm programs were $17.7 billion for 1987, and his estimates yi a net social cost (corresponding to Harberger triangles of resou distortions in commodity markets) of $6.0 billion per year (see a Council of Economic Advisers). Adjusting these estimates for *MV* of, say, 20% to 50%, the full taxpayer costs are $21.2 billion $26.6 billion in 1987. The corresponding net social costs are $ billion to 14.9 billion, between 50% and 150% greater than conventional estimates. Because the marginal welfare costs are u certain, these estimates are conjectural.

static analysis of the effects of the excess burden of taxation on the normative efficiency ranking of a range of alternative policy instruments. The analysis, which draws heavily on Gardner (1983, 1987a, c) for concepts and its approach, is concerned with efficient redistribution to farmers in terms of minimizing the total costs to consumers and taxpayers of achieving a given increase in producer surplus. This is equivalent to minimizing the excess burden of achieving a given net benefit to farmers from farm programs. The analysis begins with the case of a closed economy and considers the relative efficiency of production controls and output subsidies. Then, policies for traded goods in a small open economy are considered.

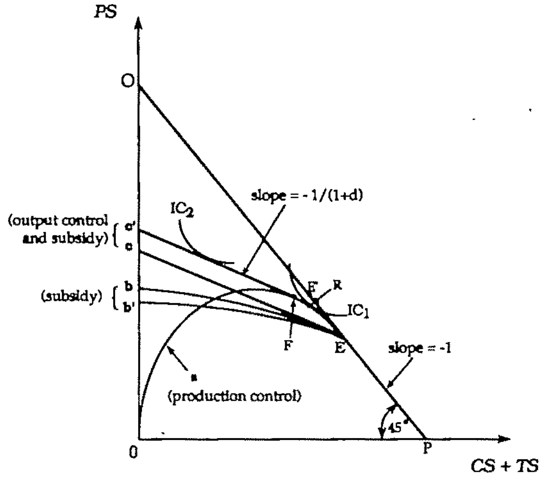

Figure 1. Efficient redistribution using production controls and output subsidies in a closed economy

Efficient Commodity Policies for a Closed Economy

Gardner (1983, 1987c) shows how the excess burden of general taxation may influence the relative efficiency of production controls and subsidies, treating the alternatives as mutually exclusive. Here we show the effects when the policies are not mutually exclusive and may be combined efficiently. Consider the simple case of a nontraded commodity when policies can involve welfare losses from distortions in both the commodity market and elsewhere in the economy (through taxes to finance farm programs). The surplus transformation curves (*STC*) in figure 1 show the trade-offs between producer surplus (*PS*) and the sum of consumer surplus (*CS*) and taxpayer surplus (*TS*) for a range of policies under various assumptions.[4] The shapes of these curves are defined by the parameters of supply and demand and the opportunity cost of government spending. The competitive equilibrium is *E*.

First, consider the case where there is no excess burden of taxes to finance subsidies in this market. A production control alone would allow transformations along (*a*); an output subsidy alone would allow transformations along (*b*) which is arbitrarily assumed to lie below (*a*) initially but to cross it eventually. Both (*a*) and (*b*) are concave, reflecting the increasing deadweight cost relative to farmer benefits as transfers away from consumers/taxpayers increase. In the case of production controls, marginal producer benefits are diminishing and eventually become negative (i.e., when quota is reduced below the monopoly maximum profit point). In the case of production subsidies, marginal producer benefits are diminishing but positive throughout.

Here, an exclusive (all-or-nothing) choice between production controls and subsidies might favor either policy, and multiple equilibria are possible, depending upon the shape of the government's indifference curves between producer surplus and consumer cum taxpayer surplus. Assume that the production control is preferred as indicated by the tangency with the indifference curve (IC_1) at point *R*. This solution is clearly inferior to point *E'*, which may be achieved by combining a subsidy with a production control holding output at the competitive quantity (Q_e). Therefore, when the opportunity cost is one dollar per dollar of government spending, it is always inefficient to specialize in either a subsidy or a production control. The most efficient option here would be to restrict output to Q_e using a quota and use a subsidy to achieve the desired transfer. Any transfer along the 45° line *OP* can be achieved in this way without any distortion in resource use, as the equivalent of a lump-sum transfer. That is, the efficient *STC* for this problem is the line *OP*.

Suppose, instead, that a dollar of subsidy program payments reduces taxpayer surplus by more than one dollar. Specifically, assume that the marginal deadweight cost of raising a dollar for

[4] Gardner (1983, 1987a) used a similar diagram; but, instead of the sum of consumer surplus and taxpayer surplus ($CS + TS$) he had, equivalently, consumer surplus less taxpayer cost ($CS - T$). The former is preferred here because it makes clearer that we are considering implications for welfare of taxpayers as distinct from the budget costs of programs.

subsidy payments is constant at d, so that a dollar of subsidy costs $(1 + d)$ dollars of taxpayer surplus. The *STC* for a subsidy alone is therefore lower at (b'). This increases the chance that an all-or-nothing choice between production controls and subsidies will favor production controls. Consider, instead, a subsidy with output fixed at the competitive quantity (Q_e), as in the previous case. The surplus transformation curve for this policy is the straight line (c) with a slope $-1/(1 + d)$. This line (c) is also the *STC* for a decoupled lump-sum transfer, which is clearly not the most efficient policy in this case. A superior option would be to combine a subsidy with a production control at the quantity corresponding to point F, where the marginal rate of surplus transformation (i.e., the slope of the *STC*, $dPS/d[CS + TS]$) for production controls equals $-1/(1 + d)$, and the marginal deadweight cost from further reductions in quantity equals the marginal deadweight cost of taxation. This option is shown by (c'), which is parallel to (c) but above it. Thus, the curve EFc' shows the efficient *STC* for this problem. In this case it may be efficient to specialize in production controls or to use a mix of policies. For example, if political preferences correspond to IC_1 a production control alone is superior. If preferences correspond to IC_2, a mix is superior, but it is never efficient to use a decoupled lump-sum transfer in this case.

Figure 2 shows, in a more familiar supply and demand setting, the efficient combination of output controls and subsidies taking account of deadweight costs of taxation. In figure 2, Q_e is the competitive output and Q_f is the optimum output quota corresponding to point F in figure

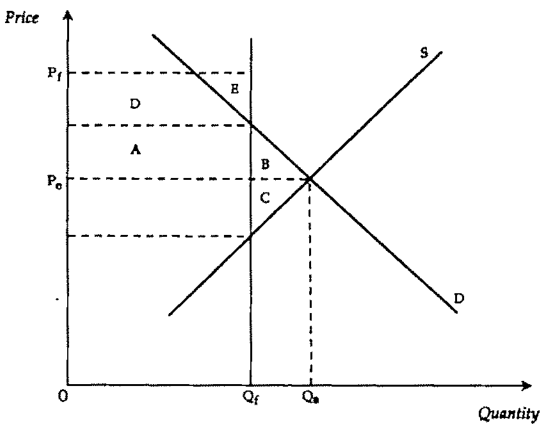

Figure 2. Effects of combining an output control and subsidy in a closed economy

1. Restricting production to Q_f yields a net pr ducer benefit equal to area $A - C$ with a co responding social cost equal to triangle $B + ($ At this point the marginal deadweight cost (raising producer benefits by the quota alone d (that is, a deadweight loss triangle $B + C$ wi increase by d cents when quota is reduced su ficiently to yield an additional dollar of pr ducer benefits in area $A - C$). For transfers producers less than $A - C$, it is efficient to u: a quota alone. For transfers greater than $A - ($ it is efficient to use a subsidy in combinatic with the quota at Q_f. In figure 2, producers r ceive a total net transfer equal to area $(A - ($ $+ (D + E)$, of which $D + E$ is in the form (output subsidy; the cost to consumers is area $+ B$; the taxpayer cost is area $(1 + d)(D + E$ the net social cost is equal to $d(D + E) + (B$ $C)$. This is the minimum social cost of achie ing that transfer given the policy options co sidered.

Efficient Commodity Policies for a Small Open Economy

Figure 3 represents a commodity market for small country importer with domestic supply (: and demand (D) and an import supply curv which is perfectly elastic at P_0. We will con pare a range of policies which confer an equi alent gain to producers equal to area $(A + B$ These are (a) a tariff of T per unit (equivale to an import quota of N with government r taining quota rents), (b) an output subsidy of per unit, (c) a production quota of Q_0 with a output subsidy of $(A + B)/Q_0$ per unit, and (a tariff of T per unit (or an import quota of $+ M)$ combined with a production quota of $($

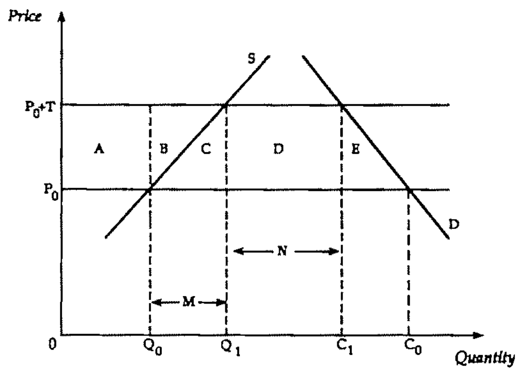

Figure 3. Efficient redistribution for a smal country importer

and a subsidy of B/Q_0 per unit. The upper half of table 1 summarizes the surplus distribution effects and deadweight losses from these alternative policies. The net column shows the deadweight losses required to achieve the transfer to producers. The most efficient policy is the one with the smallest deadweight loss.

The upper half of table 2 represents these deadweight losses algebraically in terms of elasticities of supply and demand and so on. To derive these expressions, the supply and demand curves were approximated linearly in terms of the following parameters valued at the competitive equilibrium: supply elasticity (ϵ), absolute value of demand elasticity ($\eta > 0$), percentage import tariff ($\tau = T/P_0$), and domestic production as a share of consumption ($k_d = Q_0/C_0$). To compare policies, the net social costs of each are expressed relative to those of the output subsidy. Then, to simplify the expressions, the net social costs for each policy (relative to the output subsidy) are expressed per dollar of con-

Table 1. Consumer, Taxpayer, and Net Social Costs of Surplus Redistribution Policies for a Small Open Economy

Policy	Consumer Cost	Taxpayer Cost	Net Social Cost
Importable			
Tariff (T)	$(A + B + C + D + E)$	$-(1 + d)D$	$(C + E) - dD$
Output subsidy (T)	0	$(1 + d)(A + B + C)$	$C + d(A + B + C)$
Quota (Q_0) plus subsidy $[(A + B)/Q_0]$	0	$(1 + d)(A + B)$	$d(A + B)$
Tariff (T), quota (Q_0) and subsidy (B/Q_0)	$(A + B + C + D + E)$	$-(1 + d)(D + C)$	$E - d(D + C)$
Exportable			
Output subsidy (R)	0	$(1 + d)(G + H + I + J + K)$	$K + d(G + H + I + J + K)$
Export subsidy (R)	$(G + H + I)$	$(1 + d)(I + J + K)$	$(I + K) + d(I + J + K)$
Quota (Q_0) plus subsidy of $(G + H + I + J)/Q_0$	0	$(1 + d)(G + H + I + J)$	$d(G + H + I + J)$
Price pooling scheme subsidy (R), Tax (W)	$(L + F + G + H + I)$	0	$(F + H + I + K)$

Notes: The entries in this table under importables correspond to the areas of surplus changes in figure 3 associated with an increase of producer surplus of area $(A + B)$. The entries under exportables correspond to a producer surplus change of $(G + H + I + J)$ in figure 4. The capital letters refer to areas in the figures, and lower case 'd' represents the marginal deadweight cost per dollar of government spending. The net social cost is equal to the consumer cost plus the taxpayer cost minus the benefit to producers.

Table 2. Efficiency Ranking of Surplus Redistribution Policies in a Small Open Economy

	Net Social Cost Relative to Output Subsidy	
Policy	Geometric Area	Algebraic Measure
Importable		
Quota (Q_0) plus subsidy $[(A + B)/Q_0]$	$-(1 + d)C$	$-(1 + d)\cdot\frac{1}{2}\cdot\tau^2\epsilon k_d$
Tariff (T)	$E - d(A + B + C + D)$	$\frac{1}{2}\cdot\tau^2\eta - d\tau(1 - \tau\eta)$
Tariff (T), quota (Q_0) and subsidy (B/Q_0)	$E - d(A + B + C + D) - (1 + d)C$	$\frac{1}{2}\cdot\tau^2[\eta - (1 + d)k_d\epsilon] - d\tau(1 - \tau\eta)$
Exportable		
Quota (Q_0) plus subsidy of $(G + H + I + J)/Q_0$	$-(1 + d)K$	$-(1 + d)\cdot\frac{1}{2}\cdot\rho^2\epsilon$
Export subsidy (R)	$I - d(G + H)$	$\frac{1}{2}\cdot\rho^2\eta c_d - d\rho(1 - \rho\eta)c_d$
Price pooling scheme: output subsidy (R) with consumption tax ($R + W$)	$(F + H + I) - d(G + H + I + J + K)$	$\frac{1}{2}\cdot c_d\gamma^2\eta - d\rho(1 + \rho\epsilon)$

Notes: The geometric areas are derived from those in table 1 by subtracting the net social cost of the output subsidy from that of the output subsidy. The parameters are supply elasticity (ϵ), demand elasticity ($\eta > 0$), import tariff rate (τ), domestic production as a share of consumption (k_d), export subsidy rate (ρ), domestic consumption as a share of production of the exportable (c_d), and the domestic consumption tax rate (γ) necessary to finance an output subsidy of ρ percent. The equations are defined per dollar of total consumption expenditure for the importable and per dollar of total revenue for the exportable. See the text for further details.

sumer expenditure in competitive equilibrium. A positive expression indicates the policy involves a greater net social cost than an equivalent output subsidy.

Considering individual policies in isolation with $d = 0$, an output subsidy is clearly superior to a tariff (or equivalent import quota) as a means of transferring income efficiently to producers. A production quota alone is useless in this setting. However, an output quota combined with a subsidy is equivalent to a lump sum transfer and more efficient than any single instrument. A tariff combined with a quota and a subsidy might be more efficient than an output subsidy (i.e., area $C >$ area E) depending on the relative slopes of supply and demand. These rankings may change completely when $d > 0$. Indeed, it is possible that the tariff policies that raise government revenues could raise the sum of taxpayer and consumer surplus while increasing producer surplus. Certainly some tariff will be superior to free trade when d is positive, even in this small country case. The combined quota and output subsidy policy remains unambiguously superior to the output subsidy alone, and the combined tariff, production quota, and subsidy remains superior to the tariff alone. However, it is not possible to rank all the policies unambiguously in general from theory alone. As shown in table 2, the ranking will depend on the sizes of the transfer, elasticities of supply an demand, the fraction traded, and the margin value of government revenue (d).

We do not formally analyze the large countr case, which is complicated because large cour try importers are always capable of improvin upon free trade by monopsonistic use of mark power. However, by analogy with the sma country results, the ranking of policies will b ambiguous. For large values of d, a tariff (pe haps in conjunction with output controls) is likel to be favored strongly over an output subsidy a means of redistributing surplus toward prc ducers.

The case of a small country exporter is show in figure 4. The curves are domestic demand (D supply (S) and export demand which is perfectl elastic at P_0. The free market equilibrium outpu is Q_0. Here we compare four policies which re sult in equivalent gains to producers equal to are ($G + H + I + J$). These are (a) an output sub sidy (R per unit), (b) an export subsidy (R pe unit), (c) an output control fixing output at Q plus an output subsidy of $(G + H + I + J)/Q$ per unit, and (d) a revenue pooling price di crimination scheme (of the type used widely i Australia and Canada) which is equivalent to a export subsidy (R per unit) financed entirely b a domestic consumption tax (W per unit).

The lower half of table 1 summarizes the su

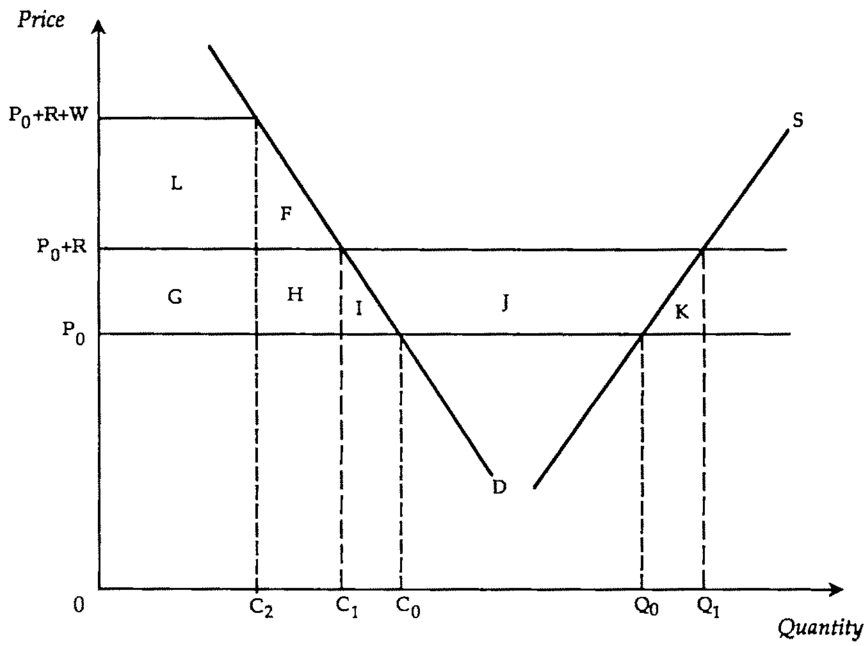

Figure 4. Efficient redistribution for a small-country exporter

plus distribution effects and deadweight losses from these alternative policies, and the lower half of table 2 represents the deadweight losses algebraically. To derive the formulas, the supply and demand curves were approximated linearly in terms of the following parameters valued at the competitive equilibrium: supply elasticity (ϵ), absolute value of demand elasticity ($\eta > 0$), percentage export subsidy ($\rho = R/P_0$), domestic consumption as a share of production of the exportable ($c_d = C_0/Q_0$), and the percentage domestic consumption tax [$\gamma = (R + W)/P_0$] necessary to finance an output subsidy of ρ percent. The net social costs of each policy are expressed relative to those of the output subsidy, scaled per dollar of producer revenue in competitive equilibrium.

Under the usual assumption ($d = 0$), a production control with an output subsidy would be the most efficient means of transferring income to producers, equivalent to a lump-sum transfer; the next most efficient policy would be a subsidy alone; third would be a subsidy on exports only; least efficient of all would be the producer price pooling scheme. These policy rankings may change when we allow $d > 0$. The quota plus subsidy option remains superior to the subsidy on all output. However, other policies may be more efficient than both of these options. The answer depends on the relative magnitudes of the marginal taxpayer costs of government spending and the marginal deadweight losses from distortions in consumption and production. In turn, these will depend on the elasticities of supply and demand, the domestic market share, and the size of the transfer to producers. For large values of d, an export subsidy could be more efficient than a subsidy on all output and a producer price pooling scheme could be most efficient.

We do not formally analyze the case of a large country exporter, which (like the case of the large country importer) is made more complicated because free trade will not maximize total domestic surplus, even when $d = 0$. When $d = 0$, the most efficient policy would be to price discriminate between domestic and export markets and transfer income to producers in a lump sum fashion through a combination of output control and subsidy. For large values of d, production controls may be the most efficient means of transferring income to producers while exploiting market power in export markets and avoiding any excess burden of government expenditure.

General Implications and Limitations of the Analysis

Our main results are three. First, the net social costs of farm programs that involve subsidies are greater, perhaps by orders of magnitude, than typical estimates suggest. Second, when the marginal welfare cost of government spending (*MWC*) is zero, it is always inefficient to specialize in single instrument policies (supply controls or subsidies); this result does not hold when *MWC* is not zero. Third, the normative efficiency ranking of alternative policies is sensitive to *MWC* (in conjunction with other factors).

The analysis has focused mainly on this third point. In the absence of deadweight costs of taxpayer surplus foregone to finance government spending, it is possible to rank the alternative policies unambiguously in terms of their relative efficiency at transferring income to producers.[5] Also, in such circumstances, it is always possible to devise a combination of commodity policies that is equivalent to a lump sum transfer to producers. However, once allowance is made for deadweight costs of taxpayer surplus, it is no longer possible to rank policies unambiguously from theory alone nor to make the equivalent of lump sum transfers. There is always a deadweight burden of either consumer surplus or taxpayer surplus, or both, and the ranking of policies is an empirical matter.

We have shown (see table 2) how the ranking of policies for traded goods may vary with changes in elasticities of supply and demand, the size of the transfer to producers (i.e., the size of the producer subsidy equivalent), the marginal opportunity cost of government spending and, for traded goods, the fraction of consumption or production traded. However, we have neglected some other factors that may influence the ranking. In particular, real-world supply controls are rarely as efficient or benign as the analysis would suggest. Output quotas are rarely freely transferable, which is a requirement for costs to be minimized. Often, the costs of limits upon quota transferability are found to be much greater than the Harberger triangles of resource distortions associated with quotas (e.g.,

[5] The information requirements to do this ranking depend upon the options being considered. When $d = 0$, for instance, in the cases analyzed in the text, there are no requirements for information about market parameters; but to compare mutually exclusive output quotas and output subsidies requires measures of elasticities of supply and demand and the magnitude of the transfer (e.g., see Gardner 1983, 1987a, c).

Lermer and Stanbury). When input controls are used as a surrogate for output controls, there are costs of distortions in input combinations to be considered (e.g., Johnson). In addition, there are administrative costs of policies and costs of rent-seeking which are likely to vary between instruments and among commodities.

Conclusion

Decisions about farm programs involve choices among policy instruments of the types considered in this paper. Typically the alternatives are analyzed by treating government spending as a transfer payment which amounts to an assumption that a dollar of government spending involves a net social cost of one dollar. This leads to a bias in the analysis in favor of policies that involve government spending relative to alternatives that do not. The growth of expenditures on U.S. farm programs during the early 1980s reflects, in part, an emphasis on the use of budgetary measures rather than regulatory alternatives to raise farm returns. In the 1985 farm bill, output subsidy policies were retained in preference to output controls, which were proposed as an alternative. This outcome may have pleased some economists who have argued for budgetary (rather than regulatory) measures because they are more transparent; but transparency did not prevent program payments reaching an all-time high of almost $26 billion in 1986.[6] The benefits of transparency may have been overstated; the costs have almost certainly been understated.

Currently it is fashionable to argue for "decoupling" farm programs in the sense that income transfers should be achieved with minimal consequences for commodity markets. Along with the benefits from transparency, the benefits from decoupling may be illusory. The issue here is whether the costs of distortions in commodity markets are necessarily greater than the costs of distortions introduced elsewhere in the economy to finance "decoupled" transfers. As with the choice between alternative commodity policy instruments, the choice between a commodity policy and a decoupled income transfer policy depends upon the answers to empirical questions which will vary among commodities.

The issue of the full taxpayer costs of government subsidies has received too little atte tion in the welfare analysis of farm program Usually the deadweight costs of taxes to rai government revenues to fund farm programs a assumed away or ignored. Occasionally the i sue is raised, but it is rarely given more weig than as a qualification to the main results. O exception is Gardner (1983). In empirical wor apart from some examples in the area of me suring returns to research (e.g., Fox), in gener a dollar of government spending in farm pr grams is assumed to cost society a dollar. O results indicate that the deadweight costs of tax elsewhere in the economy are too important be ignored in analyzing farm programs.

[6] This is not to say that transparency had no effect. It may be that less transparent policies would have involved greater implicit transfers to farmers.

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Revenue-Neutral Tax Policies Under Price Uncertainty

Garth J. Holloway

The firm's response to revenue-neutral taxation is investigated under price uncertainty. Revenue-neutral policies adjust simultaneously the marginal tax rate and the level of exemptions while keeping expected tax receipts constant. Nonincreasing absolute risk aversion is sufficient to sign the firm's response: a reduction in the marginal rate causes the firm to contract output. Implications are established for the equilibrium level of treasury receipts.

Key words: price uncertainty, risk aversion, tax policy.

Several authors have recently investigated the competitive firm's response to a change in the marginal tax rate when the product price is random. This response depends on the decision maker's absolute and relative risk aversion (Katz) or, equivalently, on the less familiar concept of partial relative risk aversion (Briys and Eeckhoudt). The results show that, in general, it is not possible to sign the firm's response by assuming that absolute risk aversion is nonincreasing in wealth.

The principal purpose here is to determine the firm's response to a revenue-neutral change in the tax rate. Such a policy adjusts simultaneously the marginal rate and the level of exemptions while keeping total tax receipts constant. The 1986 Tax Reform Act is an example of such a policy in which marginal tax rates were lowered (Hanson and Bertelsen, p. 1014; Lins, Offutt, and Richardson, p. 1022). It is shown that nonincreasing absolute risk aversion is sufficient to sign the firm's response and that a reduction in the marginal rate causes the firm to contract output. The intuition behind this result is given below, following the development of a simple model of supply response under price uncertainty. Conditions are given under whic[h] the equilibrium level of tax receipts is likely t[o] rise.

The Model and Results

Consider a competitive firm producing output x, facing random price, p, and operating wit[h] cost structure $C(x) = c(x) + f$, such that $c(0) =$ 0 and $c'(x) > 0$. When faced with a tax schem[e] comprised of profits that are exempt from tax ation, $Y \in [0, px - C(x)]$, and a constant mar ginal tax rate, $\tau \in (0, 1)$,[1] the firm solves

$$(1) \quad \max_x: E\{U(W_o + [px - c(x) - f][1 - \tau] + Y\tau)\}$$

where E is the expectations operator defined ove[r] p; U denotes risk-averse preferences such tha[t] $U' > 0$, $U'' < 0$, and $R_a(W) \equiv -U''(W)/U'(W[)]$ is nonincreasing in W; and $W = W_o + \Pi(x)$ where W_o is initial wealth and $\Pi(x)$ is profit.

Necessary and sufficient conditions for [a] maximum, after factoring out the nonzero con stant, $[1 - \tau]$, are, respectively,

$$(2) \qquad E\{U'(W)[p - c'(x)]\} = 0,$$

$$(3) \qquad E\{U''(W)[p - c'(x)]^2[1 - \tau] - U'(W)c''(x)\} \equiv \phi(x; Y, \tau) < 0.$$

Assume that $\tilde{x}$ is the nonzero, finite, and uniqu[e] solution to (2) and that (3) is satisfied. Onc[e] product price p is realized, an industry com

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[1] A flat rate of tax above an exemption is perhaps the simple[st] form of a progressive tax and is commonly referred to as a d[e]gressive tax (see, e.g., Browning, p. 288).

prised of n such firms makes tax payments to the treasury in the amount,

$$(4) \qquad \tilde{G} = n\tilde{g} = n[p\bar{x} - c(\bar{x}) - f - Y]\tau.$$

When price is random, the fiscal authority chooses the levels of Y and τ with incomplete information about p. A revenue-neutral tax policy consists of combinations of Y and τ that keep the expected level of fiscal receipts constant. Taking expectations and totally differentiating in (4), the policy satisfies

$$(5) \qquad \left.\frac{\partial Y}{\partial \tau}\right|_{dE\{\tilde{G}\}=0} = \frac{\mu_p \bar{x} - c(\bar{x}) - f - Y}{\tau},$$

where $\mu_p = E\{p\}$.

To determine the effect on output of policies defined by (5), implicitly differentiate in the first-order condition, (2), and evaluate the resulting expression at $x = \bar{x}$. This yields a Slutsky equation of the form,[2]

$$(6) \qquad \left.\frac{\partial x}{\partial \tau}\right|_{dE\{\tilde{G}\}=0} = \frac{\partial x}{\partial \tau} + \frac{\partial x}{\partial Y} \cdot \left.\frac{\partial Y}{\partial \tau}\right|_{dE\{\tilde{G}\}=0.}$$

The first term on the right-hand side is the direct effect on output of a change in τ; the second term is the indirect effect induced by the change in Y that results from constraining the expected level of receipts in accordance with (5). This reduces to

$$(7) \qquad \left.\frac{\partial x}{\partial \tau}\right|_{dE\{\tilde{G}\}=0} = \frac{\bar{x}}{\phi} E\{[U''(\tilde{W})[p - c'(\bar{x})][p - \mu_p]\},$$

which is strictly positive under nonincreasing aboslute risk aversion (Ishii). Thus, a revenue-neutral reduction in the marginal tax rate causes the firm to contract output.

In the general case investigated by Katz and by Briys and Eeckhoudt, a *ceteris paribus* reduction in the tax rate increases both the mean and variance in the firm's profits, which causes conflicting impacts on the firm's output. Under revenue neutrality a decline in the marginal rate increases the variance in profits but leaves the mean unchanged. It is well known that a risk-averse firm will contract output in response to a marginal increase in uncertainty (Ishii), and thus the sign in (7) is positive.

It is easy to establish that the variance in profits and the variance in tax payments move in opposite directions as a result of the tax change because

$$(8) \qquad \frac{\partial \text{var}(\Pi)}{\partial \tau} = \frac{\partial \text{var}(g)}{\partial \tau} \cdot [(\tau - 1)/\tau].$$

This yields an additional interpretation of the policy: a revenue-neutral change in τ shifts the share of the risk in profits between the firm and the treasury.

It remains to determine the effect of the policy on the equilibrium level of treasury receipts. The latter is distinguished from (4) by writing $\mu_p = \mu_p(X)$, where $X = nx$. This acknowledges that the supply response to the tax change can alter the price distribution, likely in the negative direction. Thus, the equilibrium level of receipts is

$$(9) \qquad \mu_G = n[\mu_p(\bar{X})\bar{x} - c(\bar{x}) - f - Y]\tau \equiv \mu_G(\bar{x}(Y, \tau); Y, \tau).$$

Totally differentiating in (9) and using (5) one obtains

$$(10) \qquad \left.\frac{\partial \mu_G}{\partial \tau}\right|_{dE\{\tilde{G}\}=0} = n\tau\mu_p \left[\frac{\partial \mu_p}{\partial X}\frac{\bar{X}}{\mu_p} + \frac{\mu_p - c'(\bar{x})}{\mu_p}\right] \left.\frac{\partial x}{\partial \tau}\right|_{dE\{\tilde{G}\}=0}.$$

Given the strictly positive term $\partial x/\partial \tau$, the effect on the mean of receipts depends on the magnitude of the terms $(\partial \mu_p/\partial \bar{X})(\bar{X}/\mu_p) \equiv \xi$ and $(\mu_p - c'(\bar{x}))/\mu_p \equiv \lambda$. The first of these is a stochastic analog of the inverse demand elasticity; it likely is negative. The second term is an index of risk aversion adapted from Sandmo [p. 67, equation (11)]; it is nonnegative and increases with increasing risk aversion. Thus, a reduction in the marginal tax rate will lower, leave unchanged, or raise the expected value of equilibrium receipts as ξ is, respectively, less than, equal to, or greater than λ in absolute value.

Concluding Comments

When the firm faces price uncertainty and the decision maker exhibits nonincreasing absolute risk aversion, a revenue-neutral reduction in the marginal tax rate causes the firm to contract output. Given an industry comprised of n such firms, the equilibrium level of transfers between the industry and the treasury may change. The level of these transfers is likely to increase when de-

[2] The author thanks Rulon Pope for this interpretation.

mand for the commodity is inelastic or when producers exhibit low degrees of risk aversion. These results help shed light on a neglected aspect of the 1986 Tax Reform Act, its possible risk-increasing effects. The magnitude of these effects, however, remains an empirical question.

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Monetary Impacts on Prices in the Short and Long Run: Some Evidence from New Zealand

John C. Robertson and David Orden

This paper presents support for long-run monetary neutrality based on evidence that individual time series for money, manufacturing prices, and agricultural prices are nonstationary but cointegrated, with a stationary proportional long-run relationship among their levels. Dynamic simulations from a vector error-correction model with this restriction imposed show that monetary shocks shift relative prices in favor of agriculture in the short run and permanently raise nominal prices. Manufacturing price shocks have similar long-run effects but initially place agriculture in a cost-price squeeze, while agricultural price shocks are transitory and have little impact on the other series.

Key words: cointegration, long-run monetary neutrality, unit roots, vector error-correction models.

Whether monetary policy has sustained effects on relative prices has been a crucial question in recent discussions of macroeconomic impacts on agriculture. At issue are whether levels of agricultural and nonagricultural prices respond proportionally to changes in the level of the money supply in the long run, and whether there are predictable deviations from such neutrality in the short run. An important hypothesis concerning these issues is that agriculture is a competitive sector in which its prices are more flexible than those in nonagricultural (fix-price) sectors. Under this hypothesis, it has been argued that expansionary monetary policy favors agriculture and may cause short-run agricultural prices to overshoot their long-run equilibrium levels, while contractionary monetary policy shifts relative prices against agriculture (Bordo; Rausser, Chalfant, and Stamoulis). Alternatively, it has been argued that price shocks arising in oligopolistic nonagricultural sectors, and accommodated by expansionary monetary policy, cause inflation and place agriculture in a cost-price squeeze (Tweeten). The short-run effects of monetary accommodation of supply shocks in agriculture and other competitive sectors have also received attention (Gordon, Van Duyne). None of these arguments about relationships among money and prices in the short run are inconsistent with neutrality in the long run if nominal prices in all sectors eventually reach new equilibrium levels proportional to the money supply. This is the long-run outcome of most theoretical models.

Empirically, a number of recent articles have utilized the impulse response functions from vector autoregression (VAR) models to investigate the relationships among monetary policy and agricultural and other prices in the short run. These articles have presented evidence of non-neutrality in Brazil (Bessler), the United States (Chambers, Orden, Devadoss and Meyers), and Canada (Taylor and Spriggs) but have generally neglected the long-run behavior of money and prices implied by their models. A VAR imposes no testable, theoretically consistent, long-run equilibrium conditions, and estimated long-run results have been viewed in some cases as "nonsensical" (Sims, Mount).

In this paper, the long-run and short-run em-

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pirical behavior of quarterly levels of money, agricultural prices, and manufacturing prices in New Zealand are analyzed jointly for the period 1963:1–1987:1. The long-run results provide evidence about the theoretical monetary neutrality hypothesis. For New Zealand, the individual money and price series appear nonstationary because of unit roots, as is often the case among aggregate macroeconomic variables (Nelson and Plosser). They also appear cointegrated, so that linear combinations of the series are stationary. Cointegration implies stable equilibrium relationships to which money and prices have a tendency to return (Engle and Granger). The cointegrating relationships found are consistent with long-run proportionality between the level of the money supply and the levels of nominal agricultural and manufacturing prices, and, hence, with neutrality of money in the long run.

Cointegration also has implications for the specification of models of the dynamic relationships among money and prices. These dynamics provide a basis for assessing the various arguments that have been made about short-run deviations from neutrality and are important for New Zealand because of the role of agriculture in the economy. To evaluate these dynamics, while imposing the long-run neutrality restriction, a vector error-correction (VEC) model is specified. In a VEC model, lagged deviations from the long-run equilibrium relationships among the cointegrated variables restrict the interactions within a system of autoregressive equations of first differences of the series. When there is cointegration, a VEC model provides more efficient parameter estimates than a VAR model in levels, while a VAR model in differences ignores information about the levels of the series and is misspecified. Thus, the VEC model provides coherent estimates of the behavior of money and prices in the short and long run. Such inferences are not obtained when support for cointegration among nonstationary series is lacking, as has been the case for money and prices in the United States (Stock and Watson, Orden and Fackler) or for commodity prices among countries (Ardeni).[1]

Organization of the paper is as follows. In the next section, some of the factors affecting the interactions among money and prices in New Zealand are described. In the third section, the stationarity properties of the money and price series are reported and the evidence of long-run monetary neutrality is presented. In the fourth section, the VEC model is specified and short-run non-neutrality hypotheses are evaluated. The final section provides a summary and some conclusions.

Structural Characteristics of the New Zealand Economy

New Zealand is a small and agriculturally trade dependent nation. The farming sector accounts for around 10% of gross domestic product (GDP) and, including processed agricultural products, around 55% of current account receipts. The economy also contains a well-developed manufacturing sector contributing some 25% of GDP. Hence, the sectoral effects of monetary policy and the dynamic relationships between the farming and manufacturing sectors in terms of relative prices, resource allocation, and profitability are important.

Historically, a variety of policies have served to insulate New Zealand from the world economy. Until 1985, domestic monetary policy and a managed exchange rate were closely coordinated and financial markets were tightly regulated. Nominal exchange-rate adjustments were undertaken periodically to maintain a relatively stable, but overvalued, real exchange rate (Rayner and Lattimore).

The manufacturing sector has received relatively high levels of import protection, primarily based on import quotas rather than tariffs. Protection levels for manufacturing have been well above their levels in other OECD countries. The manufacturing sector has also been characterized by a highly centralized wage-setting process with cost-plus-markup pricing policies (Chapple).

In contrast, the agricultural sector has been primarily an export sector and a price taker in international markets. Although a variety o

[1] With the exception of Taylor and Spriggs, who difference their money and price series, the VAR models of short-run monetary impacts cited above were estimated using levels of potentially nonstationary data. A comparative analysis is beyond the scope of this paper, but it would be interesting to examine the robustness of the estimated dynamics from each of these previous studies with an emphasis on tests for nonstationarity and cointegration and model specification based on the results of these tests. Spriggs is currently evaluating whether cointegration affects the specification of his model and has found evidence of cointegration of money and a numbe of disaggregated price series in Canada. For the United States, w do not find evidence of cointegration among nonstationary serie for money and indices of agricultural and manufacturing prices Evidence of structural change during the 1963:1–1987:1 perio complicates making a direct comparison to our results for New Ze land.

support programs have been implemented, agriculture has received relatively low levels of direct producer assistance (Lattimore). With managed exchange rates, volatility in world prices has been reflected in domestic prices. Some exchange-rate adjustments have been undertaken to insulate domestic agriculture from world price fluctuations (for example, the New Zealand dollar was appreciated in 1972–73 and was depreciated in 1975–76). Agriculture has also been subject to various domestic stabilization programs, particularly in the early 1980s, but these policies have never fully offset changes in world prices (Johnson).

With chronic overvaluation of its currency and protection of its manufacturing sector, New Zealand has experienced continual deterioration of its current account balance since the mid-1970s. Widespread wage-price controls were implemented in June 1982 in an attempt to reduce a high domestic inflation rate. These controls became untenable when government deficits reached 9% of GDP and the current account deficit 4.0% of GDP in 1984. As a consequence, the newly elected Labor Government initiated a broad liberalization of the economy aimed at deregulation of financial markets (including floating the New Zealand dollar in March 1985), reduced levels of regulation and direct assistance to specific industries (including elimination of most producer assistance and stabilization programs for agriculture during 1985), and gradual elimination of the import substitution bias of trade policy through reduction of tariffs and other import barriers.

Long-Run Neutrality

The relationships among money and prices in New Zealand were modeled using quarterly data on the money supply, $M1$, manufacturing prices, IP, and agricultural prices, FP. The data are from the Reserve Bank and Department of Statistics data bases and are transformed by taking logarithms. The measure of money is the level of $M1$ (currency plus demand deposits), and the prices are nominal producer output price indices excluding taxes and subsidy payments. The data are plotted in figure 1. Levels of money and the two price indices have risen over time, with agricultural prices exhibiting more variability than manufacturing prices or money.[2]

Long-run monetary neutrality implies a stable equilibrium relationship in which levels of nominal manufacturing and agricultural prices are proportional to the money supply. However, if the individual series are nonstationary because of unit roots, then linear combinations of the series are generally nonstationary and the series have no tendency to move together over time. The long-run neutrality hypothesis requires that some stationary relationships exist among money and prices, which will be the case when the series are cointegrated. For an N-dimensional nonstationary vector Y_t of cointegrated series, one or more vectors $\alpha_i \neq 0$ exists such that $\alpha_i'Y_t = z_{it}$ is stationary (Engle and Granger). The vector α_i is called a cointegrating vector and the z_{it}'s (the error-correction terms) are deviations from the long-run equilibrium. When the series are cointegrated, the long-run relationship $\alpha_i'Y_t = 0$ will tend to be reestablished after disequilibrating shocks. For the neutrality hypothesis to hold requires in addition that the coefficients of the long-run relationship between money and each price series be unity, so that prices are proportional to money in equilibrium.

Stationarity of the Money and Price Series

Tests to determine the stationarity characteristics of the individual money and price series are summarized in table 1. The null hypothesis is that an autoregressive representation of each series contains a unit root. This hypothesis is tested against the alternative that the autoregressive representation is stationary around a linear time trend. The tests are based on OLS-estimated equations in levels reparameterized as

$$(1) \qquad x_t = \beta_0 + \beta_1 t + \beta_2 x_{t-1} + \sum_{i=1}^{p} \beta_{2+i}\Delta x_{t-i} + e_t,$$

where $\Delta x_{t-i} = x_{t-i} - x_{t-i-1}$. A third-order model was selected for money and manufacturing prices and a fifth-order model for agricultural prices based on Sims' modified likelihood ratio tests. Results of the Dickey-Fuller τ_τ test for a unit root ($\beta_2 = 1$) and Φ_3 test of the joint hypothesis of a unit root with drift but no time trend ($\beta_1 = 0$, $\beta_2 = 1$) are reported. The unit-root hypothesis is not rejected at the 0.10 level for any of the series on the basis of either test. Conditional

[2] The initial data was seasonally unadjusted. Possible seasonality in the series was investigated by examining autocorrelation functions and the joint significance of seasonal dummy variables in univariate forecasting equations for each variable. Only the money supply variable exhibited strong seasonality, which was adjusted for via the Holt-Winter smoothing technique as described in Doan and Litterman.

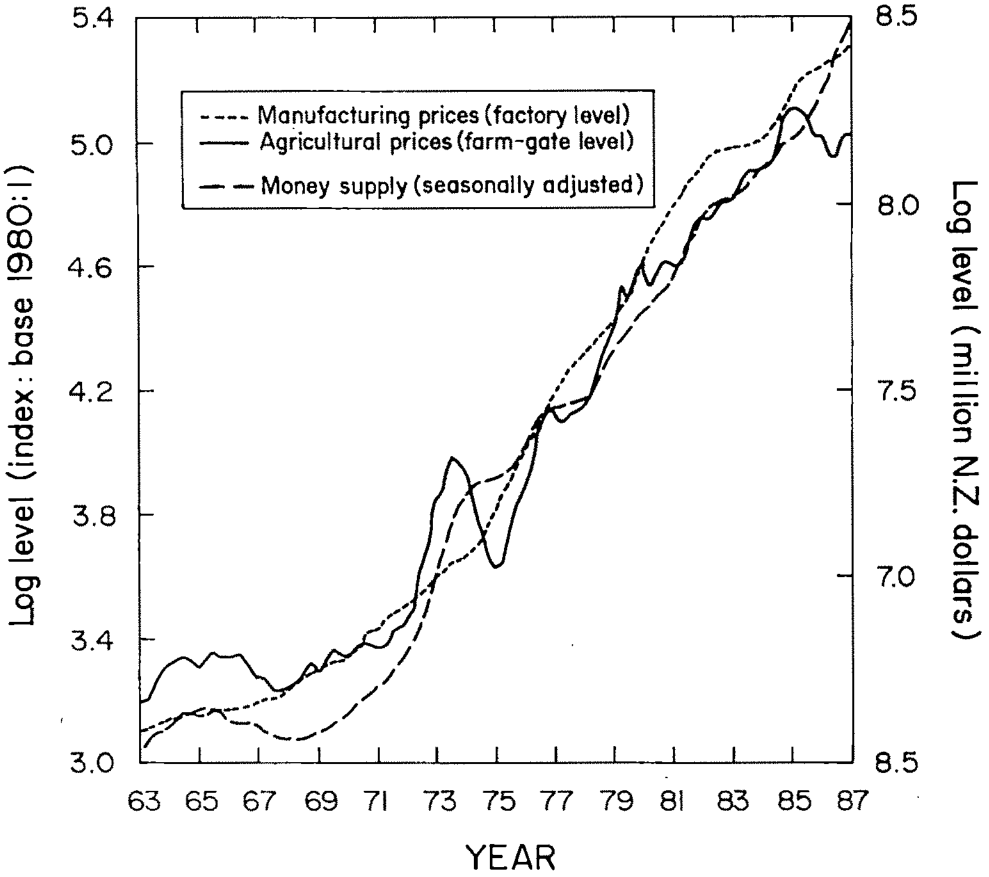

Figure 1. The money supply (*M*1), manufacturing prices, and agricultural prices in New Zealand, 1963:1–1987:1

on this result, a zero drift component is rejected at the 0.05 level for all three series.

Acceptance of the hypothesis that each series contains a unit root is also conditional on the statistical adequacy of the estimated autoregressive models. Therefore, results of several misspecification tests under the null hypothesis (a unit root and drift) are reported in the lower half of table 1. The results generally support the statistical validity of the maintained specifications. The models have reasonable explanatory power, with higher adjusted R^2's and lower estimated regression standard errors for $\Delta M1$ and ΔIP than for ΔFP. Modified Lagrange multiplier tests (denoted *LM*) provide evidence that the errors are not serially correlated (Spanos, p. 542) and skewness-kurtosis tests (denoted *SK*) suggest they are normally distributed (Bera and Jarque). The *ARCH* statistic developed by Engle indicates whether the conditional variances behave autoregressively. The possibility that the variances follow a fourth-order autoregression is not supported, relative to the null that the variances are constant, although there is weak evidence of an *ARCH* effect in the ΔFP equation.

To examine time-dependency of the parameters of the univariate models, tests were undertaken to determine whether the conditional variances are constant over subsamples of relative stability (1964:2–1971:4) and instability (1974:1–1987:1) in the world economy. These tests (denoted *VS*, Spanos p. 484) yielded mixed results; variance stability is rejected for the ΔFP regression residuals at the 0.01 level and the $\Delta M1$ residuals at the 0.05 level. Despite this evidence of instability among the variances, recursive estimation (not shown) indicates quite stable parameter estimates for all three models, except during the 1972–74 period. Moreover, constant variances over the sample and post-sample periods are not rejected when the sample period ends in 1985:4. Chow tests for predictive stability over 1986:1–1987:1 then provide little evidence that changes in the parameters have a

Table 1. Time-Series Properties of Money and Prices in New Zealand

$T = 93(1964{:}1\text{–}1987{:}1)$

Stationarity Statistics

Hypothesis	Series $M1$	IP	FP[f]
Unit root			
Dickey-Fuller (τ_τ)[a] $(\beta_2 = 1)$	−2.545	−2.542	−2.484
Dickey-Fuller (Φ_3)[b] $(\beta_1 = 0, \beta_2 = 1)$	4.940	3.489	3.665
Drift[c] $(\beta_0 = 0$, given $\beta_1 = 0, \beta_2 = 1)$	2.045***[g]	2.137**	2.833***

Summary and Misspecification Statistics

Statistic	Distribution	Series $\Delta M1$	ΔIP	ΔFP[f]
$\bar{R}^2$		0.64	0.54	0.26
$\sigma\%$		1.13	1.14	4.19
LM	$F(4,83)$	0.90	0.32	1.66
SK	$\chi^2(2)$	0.40	0.77	1.38
ARCH	$\chi^2(4)$	3.13	5.08	9.29*
VS[d]	$F(49,28)$	2.02**	1.21	3.62***
CHOW[e]	$F(5,84)$	2.08*	0.52	0.89

[a] Significance level of the test statistic based on the distribution reported for $T = 100$ in Fuller (p. 373); 10% critical value = −3.15.
[b] Significance level of the test statistic based on the distribution reported for $T = 100$ in Dickey and Fuller; 10% critical value = 5.47.
[c] Test statistic follows standard t-distribution.
[d] Test for conditional variance stability between the subsamples 1964:1–1971:4 and 1974:1–1987:1.
[e] Test for post-sample predictive stability for 1986:1–1987:1 with the model estimated through 1985:4.
[f] For FP, $T = 91$ (1964:3–1987:1); for ΔFP, distributions of *LM*, *VS*, and *CHOW* are $F(4,81)$, $F(47,24)$ and $F(5,80)$, respectively.
[g] Single asterisk indicates reject null hypothesis at the 0.10 level; double asterisk indicates reject null hypothesis at the 0.05 level; triple asterisk indicates reject null hypothesis at the 0.01 level.

statistically significant impact on the forecasting performance of the models, as shown in table 1. Thus, autoregressive models with time-invariant coefficients provide reasonable representations of the money and price series and the hypothesis that each series contains a unit root is supported.

Cointegration and Neutrality

Tests for cointegration among money, manufacturing prices, and agricultural prices in New Zealand were undertaken conditional on the hypothesis of a unit root and drift in each of the univariate models. Because a cointegrating relationship involves at least two variables, there are at most $r \leq N - 1$ linearly independent cointegrating vectors among N variables. In particular, if money is cointegrated with both manufacturing prices and agricultural prices, the cointegrating relationships can be expressed by

$$\alpha' Y_t = Z_t, \tag{2}$$

where

$$\alpha' = \begin{bmatrix} \alpha_1' \\ \alpha_2' \end{bmatrix} = \begin{bmatrix} 1 & \alpha_{12} & 0 \\ 1 & 0 & \alpha_{23} \end{bmatrix}; \tag{3}$$

$$Y_t = \begin{bmatrix} M1 \\ IP \\ FP \end{bmatrix}; Z_t = \begin{bmatrix} z_{1t} \\ z_{2t} \end{bmatrix}.$$

The vectors α_1', α_2' span the space of cointegrating relationships among money and the two prices. Stock has shown that OLS provides consistent estimates of the cointegrating parameters [$-\alpha_{ij}$ in (3)] in static bivariate regressions of current-dated variables in levels (with a constant included to adjust for differences in means). The residuals from these regressions provide estimates of the error-correction terms, and tests for cointegration are based on testing for a unit root in these series of residuals. Long-run monetary neutrality implies $\alpha_{12} = \alpha_{23} = -1$, while any linear combination of the two vectors provides an equivalent expression of cointegration.

Estimates of the cointegrating parameters from bivariate regressions among the money and price series are reported at the top of table 2. For completeness, the results from all possible bi-

Table 2. Cointegrating Vectors and Tests for Cointegration among Money and Prices

$T = 93(1964{:}1-1987{:}1)$

	Dependent Variable					
	*M*1		*IP*		*FP*	
Regressor	*IP*	*FP*	*M*1	*FP*	*M*1	*IP*
Cointegrating regressions						
Estimate of $-\alpha_{ij}$[a]	0.85	0.95	1.14	1.13	1.04	0.86
R^2	0.97	0.97	0.98	0.98	0.97	0.97
Cointegration tests[b]						
Unrestricted model	−2.88	−3.65**[c]	−3.00*	−5.41***	−3.77**	−5.45***
Restricted model ($-\alpha_{ij} = 1$)	−2.65	−3.69**	−2.65	−3.29**	−3.69**	−3.29**

[a] The coefficient α_{ij} is the only unknown coefficient of a bivariate cointegrating vector [α_i' in (3)] normalized so the coefficient of the dependent variable is one.
[b] Augmented Dickey-Fuller test for a unit root in the residuals from the cointegrating regression. Significance level of the test statistic based on the distribution for $T = 100$ in Engle and Granger; 10% critical value = −2.91.
[c] Single asterisk indicates reject null hypothesis at the 0.10 level; double asterisk indicates reject null hypothesis at the 0.05 level; triple asterisk indicates reject null hypothesis at the 0.01 level.

variate regressions are reported. The estimated cointegrating parameters are concentrated around a value of one, as implied by the neutrality hypothesis, and reversing the dependent and independent variables produces approximately inverse parameter estimates.[3]

Results of the tests for cointegration are reported in the lower part of table 2. For each test, the null hypothesis is no cointegration and the residuals contain a unit root. The alternative hypothesis is that the variables in the corresponding regression are cointegrated and the residuals are stationary. The tests are based on fourth-order autoregressive models of the residuals with the distribution of the Dickey-Fuller test statistic adjusted for its dependence on the estimated cointegrating parameters.

As shown in table 2, the null hypothesis that the residuals contain a unit root is rejected at the 0.01 level for an *IP*,*FP* regression in either direction. For the *M*1,*FP* regressions, a unit root is rejected at the 0.05 level. The results for *M*1,*IP* are less conclusive, but a unit root in the residuals is rejected at the 0.10 level for one of the regressions. Thus, it appears there are long-run equilibrium relationships among the levels of money and prices. Failure to reject a unit root in the residuals of the *M*1,*IP* regressions at the same level of significance as in the other cases may result from the low power of the tests because, by transitivity, if *IP*,*FP*, and *M*1,*FP* are cointegrated, then, equivalently, *M*1,*IP* are also cointegrated.

[3] The parameter estimates also come close to satisfying the transivity that would arise from determining the coefficient of any third equation algebraically from estimated parameters of the two other equations.

Because the estimated cointegrating parameters are close to unity, the long-run relationships between the level of the money supply and of each of the nominal prices are close to proportional. To test the long-run neutrality hypothesis, the parameters were restricted to unity in the cointegrating regressions and the residuals were tested for unit roots.[4] The results for the restricted models shown in table 2 are generally similar to those shown for the unrestricted model and suggest that the money and price series are cointegrated when the proportionality restrictions are imposed. Cointegration is supported at the 0.05 level for the *M*1,*FP* and *IP*,*FP* regressions; however, cointegration is not supported at the 0.10 level for the restricted *M*1,*IP* relationship.

To further explore the evidence of long-run neutrality from the cointegrating regressions among money and prices, a time series for real GNP, as a measure of output, and the relationship between real GNP and the money supply were also examined. A unit root was not rejected at the 0.10 level in a third-order univariate autoregressive model of the real GNP series (the Dickey-Fuller τ_τ statistic was −2.1). Cointegration tests failed to reject the hypothesis that money and real GNP are not cointegrated at the 0.10 level. With a unit root in each series and no cointegration, a model of first differences of

[4] These tests determine only whether or not the neutrality hypothesis is consistent with stationary equilibrium between money and prices. Formal hypothesis tests on the parameters of the cointegrating vectors are difficult to carry out because the asymptotic distributions of the OLS estimators are nonnormal and depend on nuisance parameters that make a general tabulation of critical values infeasible (Stock).

money and real GNP was specified to evaluate the relationship between their growth rates. Granger causality from growth rates of money to growth rates of real GNP was rejected [$F(3,86) = 2.02$]. This lack of evidence of effects of money on output corroborates the long-run monetary neutrality result apparent in the behavior of money and prices.

Dynamics of Money and Prices

Cointegration among the variables in Y_t has several implications for estimation of dynamic models, inference, and forecasting. It implies rank-reducing restrictions on the coefficients of a moving-average representation of Y_t in first differences and on the coefficients of an autoregressive representation of Y_t in levels. Engle and Granger have shown that a useful way to impose these restrictions is by a vector error-correction model of the form

$$(4) \qquad \sum_{s=0}^{P} A_s \Delta Y_{t-s} = -\gamma Z_{t-1} + U_t,$$

where $A_0 = I$, U_t is a vector of one-step-ahead forecast errors, and γ is an $N \times r$ matrix of parameters ($\gamma \neq 0$). Engle and Granger suggest a two-step procedure for estimating a VEC model using the residuals from preliminary cointegrating regressions as estimates of the error-correction terms.

In a VEC model, one-period-lagged deviations from the long-run equilibrium relationships among the cointegrated variables affect the dynamic interactions in a system of equations of first differences of the series through the γ matrix. In this model, short-run dynamics are flexible, while the long-run constraints among levels of the series implied by cointegration are imposed. The model allows the error-correction process that returns the system to equilibrium to be gradual so it can produce accurate forecasts of responses to disequilibrating shocks over reasonable horizons (Hendry). Because all of the terms in the model are stationary, standard asymptotic results for parameter estimation and hypothesis testing apply and the autoregressive model can be inverted, validating dynamic simulations based on a moving-average representation. Sims, Stock, and Watson have shown that standard asymptotic distribution theory can also be applied to a model in levels involving cointegrated variables. However, a VAR in levels omits the constraints on its parameters implied by cointegration. Hence, a levels model produces long-run forecasts that are consistent but are inefficient (Engle and Yoo). A VAR in first differences is nested within the VEC specification but is misspecified for cointegrated series because it omits the error-correction terms.

Based on the evidence of cointegration among money and prices in New Zealand, the two-step procedure was used to estimate a three-variable VEC model by OLS. First differences of each series were regressed against a constant, the error-correction residuals from the restricted *IP,FP* and *FP,M*1 cointegrating regressions, and lags of the first differences of each series. A third-order model was chosen based on Sims' modified likelihood ratio tests and Akaike's information criterion, as shown at the top of table 3.

Estimation results and misspecification statistics for each equation in the VEC model are presented at the bottom of table 3. The adjusted R^2s from the estimated forecasting equations are higher, and the equation standard errors are lower, than those reported for the univariate models for $\Delta M1$ and ΔFP. The *LM* tests provide no evidence that the errors are serially correlated, and the *SK* statistics indicate they are normally distributed. There is more evidence of an *ARCH* effect in the $\Delta M1$ equation and less in the ΔFP equation than in the univariate models, and there remains evidence of conditional variance instability in these equations. However, recursive least squares estimates of the parameters (not shown) are again stable (except during 1972–74) and Chow tests for predictive stability over 1986:1–1987:1 provide no evidence of parameter changes having a significant impact on the predictive performance of the model. Overall, these results imply that the VEC model is a reasonably robust statistical model. The evidence from the cointegration tests that a VEC model is an appropriate specification is supported by rejection of the restriction that the coefficients of the error-correction terms are jointly zero. The calculated likelihood ratio statistic (not shown in table 3) is $\chi^2(6) = 14.73$, which is significant at the 0.05 level.

Structural Specification and Simulation Results

To trace the dynamic effects of various shocks, the estimated VEC model was reparameterized to its equivalent formulation in levels. With this reparameterization, the error-correction terms are incorporated into the first-period lagged terms of the autoregression. The model can then be

Table 3. Summary and Misspecification Statistics for the VEC Model

Lag Length Selection

	Number of Lags					
Test	6	5	4	3	2	1
Modified Likelihood ratio test[a]		7.23	9.98	8.36	21.71***[d]	16.93**
Akaike's Information Criterion	−23.74	−23.84	−23.91	−24.00	−23.93	−23.92

Summary and misspecification statistics

Statistic	Distribution	Series		
		$\Delta M1$	ΔIP	ΔFP
$\bar{R}^2$		0.71	0.54	0.40
$\sigma\%$		1.03	1.13	3.73
LM	$F(4,77)$	0.64	0.99	1.07
SK	$\chi^2(2)$	1.70	0.17	1.12
ARCH	$\chi^2(4)$	8.52*	3.07	4.34
VS[b]	$F(41,20)$	2.19**	1.19	3.58***
CHOW[c]	$F(5,76)$	1.99	0.99	1.64

[a] Test statistic follows a χ^2 distribution with 9 degrees of freedom.
[b] Test for conditional variance stability between the subsamples 1964:1–1971:4 and 1974:1–1987:1.
[c] Test for post-sample predictive stability for 1986:1–1987:1 with the model estimated through 1985:4.
[d] Single asterisk indicates reject null hypothesis at the 0.10 level; double asterisk indicates reject null hypothesis at the 0.05 level; triple asterisk indicates reject null hypothesis at the 0.01 level.

inverted to obtain impulse response functions that capture the effects of deviations from long-run equilibrium on the dynamic paths followed by each variable in response to initial shocks.

While tests of the long-run neutrality hypothesis are not dependent on identification of the sources of stochastic deviations from the long-run equilibrium, interpretation of the dynamic relationships from the VEC model requires structural identifying assumptions. Although one must be cautious about structural interpretation because many potential sources of variation are aggregated in the error term of each equation, in the remainder of this analysis the model is interpreted as describing the policy-setting behavior of the monetary authority and reduced-form equations for each sector capturing the likely responses of agricultural and manufacturing prices to shocks of monetary and sectoral origins. Assuming a recursive model then allows a structural interpretation based on a Choleski decomposition of the covariance matrix of the model's one-step-ahead forecast errors.

Impulse response functions showing the responses to one-standard-deviation positive shocks to each variable and their 90% confidence bounds were calculated for the VEC model for several recursive orders using a Monte Carlo integration algorithm with 200 draws from the posterior distribution of each response estimate (Doan and Litterman). The results are essentially invariant to the recursive order and are plotted for the order $M1,IP,FP$ in figure 2 for a twenty-quarter forecast horizon. This model allows money supply shocks the most opportunity to affect the price variables by attributing to the monetary shock any contemporaneous correlations among the forecast errors for money and prices.

The point estimates from the impulse response functions show that the dynamic responses of money and prices depend on the source of the initial shock. The long-run percentage responses to a given shock are approximately equal among the three variables. This reflects the long-run equilibrium imposed by the unitary cointegrating vectors. After any given shock, equality of the point estimates of the impulse responses occurs around thirty quarters.

While further interpretation of the point estimates of the impulse responses shown in figure 2 must be qualified because of their estimated standard errors, the mean responses suggest several observations about the likely time paths of money and prices after specific shocks. In particular, a positive monetary shock raises the levels of the money supply, manufacturing prices, and agricultural prices in the long run. Agricultural prices are immediately responsive to the monetary shock and display some indication of a cylical response pattern, while manufacturing prices start to respond only after a lag of four quarters. With managed exchange rates and agriculture being a price taker in world markets, that positive monetary shocks induce a shift in

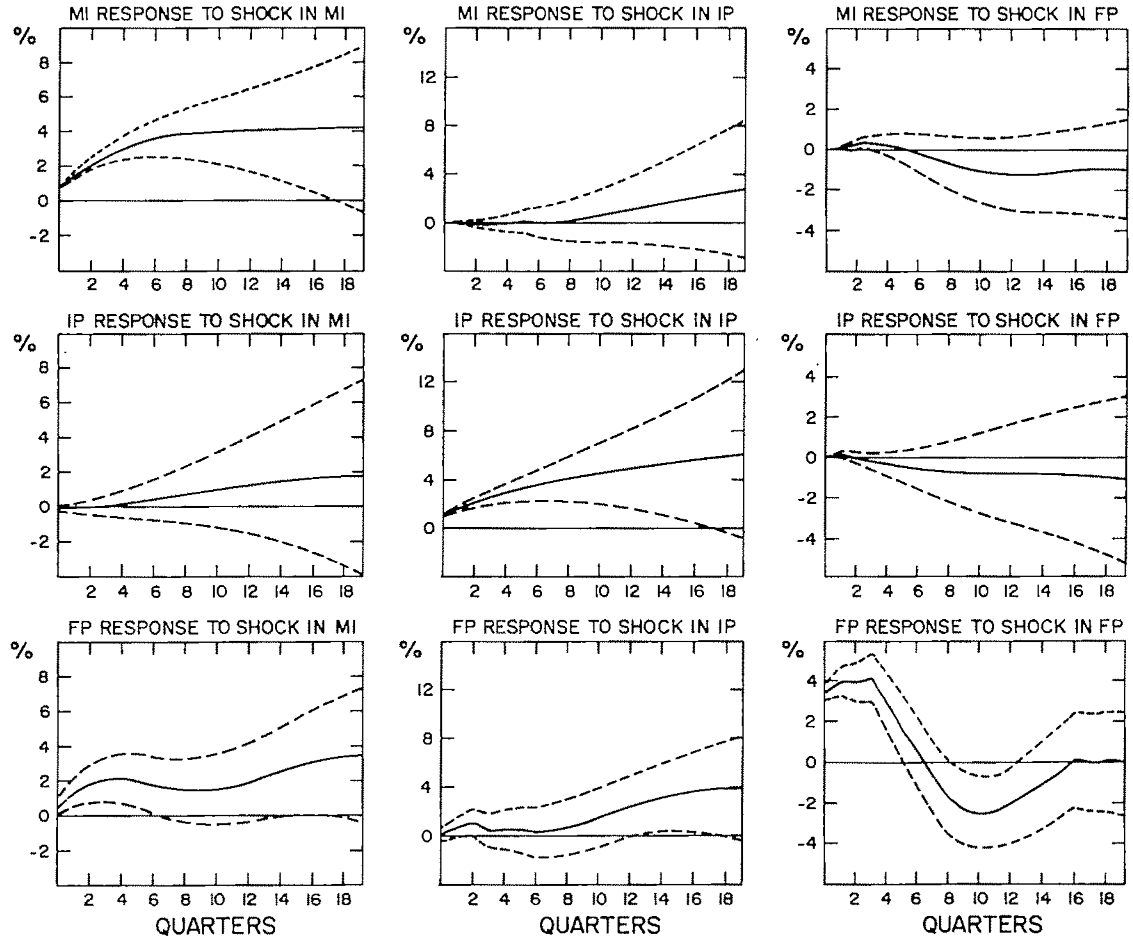

Figure 2. Responses to one-standard-deviation shocks from VEC model of money, manufacturing prices, and agricultural prices

relative prices in favor of agriculture in the short run implies that monetary expansions have been associated with nominal devaluations before domestic manufacturing prices rise. Agricultural prices do not respond more than proportionately or overshoot their long-run equilibrium level in response to a monetary shock, as might be the case if exchange rates were flexible and were to overshoot their long-run equilibrium values in response to monetary policy.

A positive shock to manufacturing prices also raises the levels of all three series in the long run. There is a lag in the response of the money supply and agricultural prices. Because of this delay, the shock to manufacturing prices initially places agriculture in a cost-price squeeze. The response of the money supply suggests a lagged accommodation of the increase in the domestic prices of manufactured goods by the monetary authority, with agricultural prices adjusting simultaneously. This autonomy of manufacturing prices, and subsequent monetary responsiveness, may not persist under the current policies for gradual liberalization of the manufacturing sector, but no evidence of structural change was found through 1987:1.

In contrast to the permanent shift in the level of each series induced by shocks to the money supply or manufacturing prices, following an agricultural price shock a new long-run equilibrium of each series is established around its initial level. The own response of agricultural prices displays a dampening oscillatory pattern. Neither the money supply nor manufacturing prices shows any significant short-run response, so there is a short-run shift in relative prices in favor of agriculture.

The failure to detect an effect of agricultural

prices on the money supply, compared to the long-run responsiveness of the money supply to shocks to manufacturing prices, also has policy implications. The lack of feedback from agricultural prices to the money supply suggests unwillingness of the monetary authority to accommodate world agricultural price shocks. Stabilization programs that retained farm earnings in the Reserve Bank during periods of high world prices and released them during periods of low prices contributed to the ability of the monetary authority to insulate New Zealand from external inflationary and deflationary pressures arising from agriculture. These stabilization programs have been eliminated since 1985. Again, no evidence of structural change was found through 1987:1. However, it remains to be observed whether the dynamic patterns of responses to agricultural price shocks will persist or whether future agricultural shocks will induce greater instability in the money supply or manufacturing prices.

It is interesting to compare the results shown in figure 1 to impulse responses from VAR models specified under alternative assumptions about the stationarity properties of the money and price series. Two VAR models were estimated: a fourth-order model in levels, under the maintained hypothesis of stationarity, and a third-order model in first differences (without the error-correction terms), under the maintained hypothesis of unit roots and no cointegration. The point estimates of the impulse responses from the VAR in levels (not shown but available on request) are generally similar to those from the VEC model. This is not surprising because the parameter estimates from a levels model are consistent for cointegrated nonstationary variables. However, with no long-run restrictions imposed, the point estimates of the impulse responses following any specific shock do not converge to common values in the levels model even after forty quarters.

In contrast, the impulse response functions from a VAR model in first differences are unlike those from the VEC model or the VAR model in levels. Estimates from the differences model (reparameterized to show the impacts of each shock on levels of the variables) suggest both a more-than-proportionate short-run response of agricultural prices to a money supply shock and a short-run tendency for agricultural prices to overshoot their long-run level. The own response to a shock to manufacturing prices is persistent in the differences model and is largely matched by the response of agricultural prices, while the money supply responds more slowly and to a lower level over a long horizon. Own responses to shocks to agricultural prices are also persistent in the differences model but do not induce responses of the money supply or manufacturing prices, suggesting a long-run shift in relative prices in favor of agriculture. Thus, inferences drawn from a VAR model in first differences without the error-correction terms would be different than those drawn from the VEC model.

Summary and Conclusions

In this paper, the stationarity properties of the data have been analyzed in order to test the hypothesis of long-run monetary neutrality and better understand the dynamic relationships among money and prices in New Zealand in the short and long run. Tests for stationarity failed to reject a unit root in autoregressive models of the individual series for money, agricultural prices, and manufacturing prices. The money and price series also appear cointegrated, with parameter estimates from unrestricted cointegrating regressions close to unity. When proportionality among levels of money and prices is imposed on the cointegrating regressions, the evidence is weaker but the restricted error-correction terms (residuals) also appear stationary. These results provide empirical support for the long-run monetary neutrality hypothesis.

Incorporating the restricted error-correction terms in a VEC model provides a description of the dynamic relationships among money and prices consistent with long-run neutrality. Monetary shocks raise the levels of prices in the long run. Agricultural prices respond more quickly than manufacturing prices, but no evidence was found that agricultural prices rise proportionately more than the money supply or overshoot their long-run levels in the short run. Shocks to manufacturing prices induce monetary expansions and place agriculture in a short-run cost price squeeze, while levels of the money supply and manufacturing prices have not responded to fluctuations in agricultural prices. These results are consistent with the historical insulation of the manufacturing sector in New Zealand and with policies to stabilize the economy in face of external shocks. Monetary responses to shocks to manufacturing prices may moderate under recent liberalization policies, and these policies may leave the economy more exposed to external shocks, but no evidence was found that policy

reforms have altered the dynamic patterns among money and prices through 1987:1.

The importance of preliminary evaluation of the stationarity properties of the money and price series is demonstrated in this analysis by a comparison of the impulse response functions from the VEC model to those from VAR models estimated under alternative stationarity assumptions. The VEC model provides more precise long-run estimates than an unrestricted VAR model in levels. The impulse response functions from a VAR model in first differences are less plausible than those of the VEC model.

Some caveats about the results also should be noted. The acceptability of an empirical model is tentative until it has been successfully tested against rival models. The VEC model presented in this paper is a small closed system that omits other theoretically relevant variables and aggregates many potential sources of variation in each of its error terms. Inferences from the model are also limited by the recursive structure imposed and by the relatively wide confidence bounds of the impulse response functions. Assuming that the data are rich enough to reveal the underlying phenomena of interest, postulating larger dynamic models with appealing contemporaneous structures and statistical properties is a priority for future research. These models will further our understanding of monetary effects on agriculture, feedback among sectors, and feedback from the sectors to monetary policy.

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Risk Analysis of Tillage Alternatives with Government Programs

Jeffery R. Williams, Richard V. Llewelyn, and G. Art Barnaby

Stochastic dominance analysis of two tillage systems, conventional tillage and no-tillage, for five crop rotations, wheat-fallow, grain sorghum-fallow, continuous wheat, continuous grain sorghum, and wheat-grain sorghum-fallow, shows that risk-averse managers prefer a conventional tillage wheat-sorghum-fallow system. Small changes in production costs or yields lead to indifference between this system and the no-tillage wheat-sorghum-fallow and no-till and conventional wheat-fallow systems. Participation in the basic government commodity program generally increases average net returns and lowers variation of returns. Government commodity program payments calculated under a variety of scenarios do not generally encourage the use of no-till practices for grain sorghum and wheat in the central Great Plains.

Key words: commodity programs, conservation tillage, grain sorghum, no-tillage, risk, stochastic dominance, wheat.

Dryland production of wheat and grain sorghum in the Great Plains is dependent on sufficient soil moisture. Low humidity and high winds contribute to the loss of soil moisture and soil erosion in this region. Conservation tillage systems, including no-tillage, reduce the potential for soil erosion and soil moisture loss. Economic evaluations of no-tillage systems are important in order to determine their effects on the level and variability of farm returns. Current government program provisions do not directly restrict tillage system selection, although they do affect crop decisions by dryland wheat-fallow farmers in the Great Plains. In addition, the assigned program yield provision can penalize a farm manager who selects a tillage system which requires and generates higher yields for increased net returns. The risk-reducing characteristics of the program influence tillage system and crop rotation selection as well.

Economic analysis of conservation tillage under government program provisions has not been well documented for no-tillage wheat and grain sorghum rotations. Studies have shown that conservation tillage generally increases wheat and grain sorghum yields relative to conventional tillage, although this is not consistently the case (Reed and Erickson; Baumhardt, Zartman, and Unger). Higher yields were attributed to higher soil moisture at planting. Variable costs have been higher for reduced tillage wheat systems; but, when machinery costs were considered, some systems were competitive (Epplin et al.). Harman compared conventional and conservation tillage grain sorghum and found significant cost reductions on the conservation tillage systems. Williams analyzed dryland tillage systems for wheat and grain sorghum in western Kansas both with and without the use of crop insurance. He concluded that risk-averse managers would prefer reduced tillage systems, given the reduced costs and increased yields. Helms, Bailey, and Glover considered the impact of government commodity programs on conservation tillage practices for a dryland wheat farm in Utah, using whole-farm simulation. They conclude that risk-averse producers prefer a combination of minimum and no-tillage with program participation. However, their study used identical yield distributions for each tillage practice, rather than actual yield data from specific tillage systems. Alternative crop rotations were not considered.

This study compares wheat and grain sorghum

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rotations grown continuously, in fallow systems, and in rotation using conventional and no-tillage methods. The impact of the 1985 Food Security Act commodity provisions on tillage system and crop rotation is also evaluated. The objective is to analyze the risk and returns of each system and the consistency of the results with the soil conservation objectives of the act. Net return distributions are first generated using historical commodity prices and then calculated using the government program provisions for the 1987 crop year. Stochastic dominance techniques are used to determine the preferred systems.

Tillage and Rotation Practices

Conventional and no-tillage practices are considered for five crop rotations. The resulting combinations of tillage and crop systems are (*a*) conventional tillage wheat-fallow (CVWF), (*b*) no-till wheat-fallow (NTWF), (*c*) conventional tillage continuous wheat (CVWW), (*d*) no-till continuous wheat (NTWW), (*e*) conventional tillage continuous grain sorghum (CVSS), (*f*) no-till continuous grain sorghum (NTSS), (*g*) conventional tillage grain sorghum-fallow (CVSF), (*h*) no-till grain sorghum-fallow (NTSF), (*i*) conventional tillage wheat-grain sorghum-fallow (CVWSF), and (*j*) no-till wheat-grain sorghum-fallow (NTWSF).

Typical conventional tillage operations for western Kansas consist of primary tillage using a V-blade sweep or disk and secondary tillage using a rodweeder in wheat and a disk in grain sorghum. Cultivation along with a single application of herbicides occurs during the growing season for weed control in sorghum. In no-tillage, weed control is achieved through herbicide application during the fallow period and prior to planting.

The length of the fallow period is a major distinction between the various crop rotations. The traditional wheat-fallow system involves a fifteen-month fallow period between harvest in July and planting the next crop in September of the following year. The sorghum-fallow system has a nineteen-month fallow period between harvest and planting. The continuous systems have no extended fallow period because the entire acreage is planted to a crop each year. Wheat-sorghum-fallow rotations have an eleven-month fallow period between wheat harvest and planting of grain sorghum and another eleven-month fallow period occurs between sorghum harvest and whea planting.

Procedures and Data Requirements

Variable inputs and general equipment require ments are determined for each cropping system based on practices of the Kansas Agricultura Experiment Station. Variable and fixed costs ar determined with regard to farm size and tenu arrangements. Specific costs for individual fiel operations are calculated and organized into whole-farm budget for each cropping and tillag combination.

Distributions of net returns to land and mar agement for each system are calculated usin yield and price data from 1976–86 and 198 costs, under both participation and nonpartic pation in the commodity program. Loan rates target prices, and acreage reduction percentage for the 1987 cropping year are used in these ca culations.

Four scenarios involving participation an nonparticipation in the government commodit program are examined: (*a*) nonparticipation, (*l* participation with an established base in a whea fallow rotation, (*c*) participation with a bas change approved to comply with soil conse vation requirements, and (*d*) participation in th optional paid land diversion for grain sorghu in addition to the conditions of scenario *c*.

Equation (1) described how each observatio of net return is estimated for both crops in eac cropping system under the government progra provisions for owned land. Returns to the o erator including deficiency and diversion pa ments on rented land are shared with the lan lord in the same ratio as yield-increasing inp costs.

$$(1)\quad \sum_{i=1}^{2} NR_{in} = \sum_{i=1}^{2} \{[(\max\{P_{in}, EL_{iN}\} * Y_{in}) - VC_{iN} - FC_{iN}] * PA_{iN} - [(MC_{iN} + FC_{iN}) * (ARP_{iN} + OPD_{iN})]\} + PAY_{in},$$

where

$$PAY_{in} = \{[DP_{in} * PA_{iN}] + [OPD_{iN} * OPDR_{iN}]\} * PY_{iN}.$$

If $\Sigma_{i=1}^{2} PAY_{in} > \$50{,}000$, then

$$\sum_{i=1}^{2} NR_{in} = \sum_{i=1}^{2} \{[(\max\{P_{in}, EL_{iN}\} * Y_{in}) - VC_{iN} - FC_{iN}] * PA_{iN} - [(MC_{iN} + FC_{iN}) * (ARP_{iN} + OPD_{iN})]\} + \$50{,}000 + \min\left\{\sum_{i=1}^{2} [(FL_{iN} - EL_{iN}) * PY_{iN} * PA_{iN}], \$200{,}000\right\},$$

where

- i = 1, 2 (1 is wheat and 2 is grain sorghum);
- n = 1, ..., N (N = 11 years);
- NR_{in} is net returns, crop i ($) for observation n;
- P_{in} is market price, crop i ($/bu.), for observation n;
- EL_{iN} is effective national average loan rate ($/bu.);
- Y_{iN} is average yield on planted acreage (bu./acre);
- VC_{iN} is variable costs of production ($/acre);
- FC_{iN} is fixed costs ($/acre);
- PA_{iN} is planted acres, crop i, where $PA_{iN} = BA_{iN} - ARP_{iN} - OPD_{iN}$;
- BA_{iN} is base acres, crop i;
- ARR_{iN} is acreage reduction requirement (% of BA_i);
- OPD_{iN} is optional paid diversion (acres);
- ARP_{iN} is acreage reduction program acres, where $ARP_{iN} = ARR_{iN} * BA_{iN}$;
- $OPDR_{iN}$ is optional paid diversion payment rate ($/bu.);
- MC_{iN} is maintenance cost for diverted acres ($/acre);
- PAY_{in} is government payments ($);
- DP_{in} is deficiency payments ($/bu.), where $DP_{in} = TP_{iN} - \max\{P_{in}, EL_{iN}\}$;
- TP_{iN} is target price ($/bu.);
- EP_{iN} is expected national average price ($/bu.);
- PY_{iN} is program yield (bu./acre); and
- FL_{iN} is formula loan rate ($/bu.).

Yields (Y_{in}) are used to calculate the gross returns on the crop actually produced. Market prices (P_{in}) are assumed to be the season average price. When returns are calculated under the government program provisions, the market price is not allowed to fall below the effective loan rate (EL_{iN}). The formula loan rates (FL_{iN}) for 1987 were $2.85 per bushel for wheat and $2.17 per bushel for grain sorghum. Effective loan rates (EL_{iN}) are $2.28 per bushel for wheat and $1.74 per bushel for grain sorghum. Target prices (TP_{iN}) were $4.38 per bushel for wheat and $2.88 per bushel for grain sorghum. The percent set-aside was 27.5% of base acres for wheat and 20% for grain sorghum in 1987. A detailed discussion of government program provisions is provided in Williams, Harper, and Barnaby.

Stochastic dominance analysis is used in each case to select efficient strategies by comparing the cumulative density functions (cdf) of possible returns for each strategy. This study uses second-degree stochastic dominance (SSD) and stochastic dominance with respect to a function (SDRF), (Cochran, Robison, and Lodwick). The solutions for the stochastic dominance analysis are found using an optimal control algorithm developed by Raskin, Goh, and Cochran.

Yields and Prices

Yield and soil moisture data were obtained from the Fort Hays Branch Experiment Station at Hays, Kansas. Crop prices are the season averages from the central district of the Kansas Crop and Livestock Reporting Service. The prices are converted to 1986 dollars using the U.S. Department of Agriculture (USDA) index of prices received by farmers.

Yield and soil moisture data are analyzed using Duncan's multiple range test to determine if the means for crop yields or soil moisture differed significantly under the ten crop systems (table 1). Continuous wheat and continuous grain sorghum have significantly lower yields than the other crop rotations. In examining tillage systems, no-tillage wheat-fallow yields are significantly higher than those of conventional tillage wheat-fallow. No significant differences occurred between yields for the other wheat rotations or sorghum due to tillage practices. Average soil moisture in no-tillage systems is significantly higher than in conventional tillage systems for each crop rotation (table 1).

The use of experiment station yield data for this type of analysis is a source of concern. Although farm data for similar tillage practices are not available for comparison with experiment plot data, yield data for dryland fallow wheat from thirty-five farms in west-central Kansas are available. The mean yield (based on harvested

Table 1. Means and Standard Deviations of Yields, Soil Moisture, and Net Returns

Yield and Soil Moisture Data[b]	Cropping System[a]									
	CVWF	NTWF	CVWW	NTWW	CVSS	NTSS	CVSF	NTSF	CVWSF	NTWSF
Yield[c]										
Wheat										
Mean	29.2B	33.1A	21.7C	23.0C					30.2AB	10.9AB
Std. deviation	8.8	7.2	7.3	8.7					10.0	7.7
Coef. of variation	30.1	21.7	33.9	38.0					33.1	24.8
Sorghum										
Mean					41.3B	41.5B	61.6A	58.4A	62.8A	69.6A
Std. deviation					23.1	22.8	29.9	25.0	24.1	28.2
Coef. of variation					55.9	55.0	48.4	42.8	38.4	40.4
Soil moisture[d]										
Wheat										
Mean	6.08B	6.52A	4.78E	5.04D					5.80C	5.99BC
Std. deviation	0.45	0.36	0.35	0.41					0.41	0.34
Sorghum										
Mean					5.23C	5.43C	6.09B	6.17B	6.04B	6.42A
Std. deviation					0.52	0.45	0.55	0.33	0.39	0.41
Mean net returns ($)[e]										
No gov't.	749	1,973	−4,810	−2,386	−13,994	−11,279	1,874	−3,950	12,490	11,810
Gov't. program	2,549	730	(−672)	(−839)	(−413)	(761)	(11,343)	(7,435)	(19,475)	(16,653)
Base change	2,549	2,306	−672	225	−413	876	11,343	6,557	19,475	18,120
15% diversion	2,549	730	(−672)	(−839)	(−2,605)	(−2,492)	(8,398)	(6,164)	(17,308)	(13,445)
Div + base change	2,549	2,306	−672	225	−2,605	−2,347	8,398	5,061	17,308	15,231
Std. dev. net returns ($)[e]										
No gov't	11,346	9,773	16,680	20,290	37,000	37,488	20,407	18,216	19,527	19,482
Gov't program	6,885	5,424	(11,293)	(13,669)	(26,256)	(26,412)	(17,542)	(15,024)	(12,837)	(12,970)
Base change	6,885	5,472	11,293	13,773	26,256	26,416	17,542	14,905	12,837	13,095
15% diversion	6,885	5,424	(11,293)	(13,669)	(19,202)	(19,304)	(13,141)	(11,259)	(10,580)	(10,306)
Div + base change	6,885	5,472	11,293	13,773	19,202	19,308	13,141	11,154	10,580	10,422

[a] CVWF is conventional tillage wheat-fallow; NTWF, no-tillage wheat-fallow; CVWW, conventional tillage continuous wheat; NTWW, no-tillage continuous wheat; CVSS, conventional tillage continuous sorghum; NTSS, no-tillage continuous sorghum; CVSF, conventional tillage sorghum-fallow; NTSF, no-tillage sorghum-fallow; CVWSF, conventional tillage wheat-sorghum-fallow; NTWSF, no-tillage wheat-sorghum-fallow.

[b] Duncan's Multiple Range Test performed for $\alpha = .05$. Letters A–E indicate the grouping of the mean. A mean with the letter A is statistically different than a mean with any other single letter such as B, and a mean with the letter B is statistically different than a mean with letter C, etc. A mean with the letter AB is not statistically different from a mean with the letter A or B but is statistically different from any other letter or combinations of letters not containing A or B.

[c] Average annual yield.

[d] Average soil moisture (inches) in a 6-foot soil profile at planting time.

[e] Net return to land and management equals gross income minus all costs except for a land and management charge, including opportunity cost on operator labor, interest expense on variable inputs, and equipment. Numbers in parentheses are for comparison only between tillage systems given the same crop rotation, or within tillage system and crop rotation across program scenarios.

acres) for dryland wheat is 34.9 bushels per acre with a standard deviation of 8.8 for continuous farm data from 1976 to 1986. This compares with average conventional tillage wheat yields on the experiment station of 29.2 bushels per acre and no-till wheat yields of 33.1 bushels per acre during the same period. Standard deviations for the experiment station data are 8.8 for conventional tillage and 7.2 for no-till. Thus, the experiment station data provide reasonable estimates of relative yield variability for the comparison of tillage and cropping systems. Sorghum yield data are not available for comparison.

Size and Tenure Characteristics

Kansas Farm Management Association data compiled by Langemeier for 130 predominantly dryland farms in west-central Kansas are used to establish the size and tenure arrangements of the representative farm. The average farm contains approximately 1,100 acres of cropland of which 33.4% is owned. The remainder is rented, typically using a crop share arrangement.

Costs

Specific tillage methods, fertilization, chemical, and seeding rates are obtained from practices at the experiment station. An equipment complement for each system is based on acreage, equipment efficiency, and time available to complete the field operations (Schrock). Labor requirements are estimated from the total time required for field operations for the necessary equipment complement. Data from Schrock, Kramer, and Clark are used to calculate per acre fuel requirements for each tillage operation. Harvesting and fertilizer application costs are based on the typical west central Kansas practice of custom hiring for these operations.

Equipment costs include charges for depreciation, average annual interest (opportunity costs), insurance and housing, and repairs. A depreciable value was determined by discounting the list price by 30% for tractors and 20% for other machinery. All equipment ages were assumed to be half of their depreciable life: tractors—five years, planting equipment—six years, and tillage implements—seven years. All equipment not used in the conventional tillage wheat-fallow system is assumed newly purchased. List price is deflated to the appropriate year of purchase to determine the original value for depreciation purposes. Salvage values are estimated as a percentage of purchase price (Bauscher and Willet). Repairs are estimated by using the hours of use for tractor and tillage implement in each field operation, initial list price, and total hours of machine use (Rotz).

Analysis and Results

In this section the results of the empirical analysis are reported for the various cropping systems under alternative provisions for the government programs.

Nonparticipation in Government Commodity Program

Conventional wheat-sorghum-fallow (CVWSF) has the highest net return followed by no-till wheat-sorghum-fallow (NTWSF) (table 1, No Gov't.). These systems also have the fewest number of losses. However, these systems have much higher standard deviations than the wheat-fallow system, indicating higher potential risk. All of the systems with sorghum included have higher standard deviations than the wheat-fallow systems.

Stochastic dominance analysis is used to find the SSD and SDRF efficient sets (table 2, No Gov't.). The efficient set in SSD includes the NTWF, NTWSF, and CVWSF systems. For SDRF, the CVWSF system is dominant in all risk intervals.

Nonparticipation Sensitivity Analysis

The magnitude of a parallel shift of the dominant distribution necessary to eliminate its dominance is also considered. In the risk preference interval of 0.00001 to 0.00005, the results are quite sensitive to changes in yield or production costs between the dominant CVWSF system and the NTWSF system. If the cdf for CVWSF is lowered by a parallel shift of \$528, it no longer dominates the NTWSF system. This is equivalent to a \$1.44 per acre increase in cost, a .47 bushels per acre wheat yield reduction, or a .71 bushels per acre sorghum yield reduction (given average crop prices). These yield differences are less than the critical difference (determined using Duncan's Multiple Range Test, $\alpha = .05$) of 3.17 bushels of wheat and 11.74 bushels of grain

Table 2. Stochastic Dominance Results of Commodity Program Participation and Nonparticipation Scenarios

	Lower R (x)	Upper R (x)	No Gov't	Government Program[a]	Program with Base Change	Program with Base Change Paid Land Diversion
SSD	0.0	+ ∞	NTWF, CVWSF, NTWSF	CVWSF, NTWSF CVWF-G, NTWF-G	CVWSF-G	CVWSF-G, CVWSF-I
SDRF	−0.00005 to	−0.00001	CVWSF	CVWSF	CVWSF-G	CVWSF-G
	−0.00001 to	0.0	CVWSF	CVWSF	CVWSF-G	CVWSF-G
	−0.00001 to	0.00001	CVWSF	CVWSF	CVWSF-G	CVWSF-G
	0.0 to	0.00001	CVWSF	CVWSF	CVWSF-G	CVWSF-G
	0.00001 to	0.00005	CVWSF	CVWSF	CVWSF-G	CVWSF-G
	0.00005 to	0.0001	CVWSF	CVWSF, CVWF-G	CVWSF-G	CVWSF-G, CVWSF-I
	0.0001 to	0.001	CVWSF	NTWF-G, CVWF-G	CVWSF-G	CVWSF-D

Note: CVWF, conventional tillage wheat-fallow; NTWF, no-tillage wheat-fallow; CVWW, conventional tillage continuous wheat; NTWW, no-tillage continuous wheat; CVSS, conventional tillage continuous sorghum; NTSS, no-tillage continuous sorghum; CVSF, conventional tillage sorghum-fallow; NTSF, no-tillage sorghum-fallow; CVWSF, conventional tillage wheat-sorghum-fallow; NTWSF, no-tillage wheat-sorghum-fallow; -G, indicates distributions with basic government program participation; -D, indicates distributions with government program participation including paid land diversion for feed grains.
[a] The government program scenario assumes base acreage exists for wheat only.

sorghum required for the yields from these systems to be significantly different. A change in yield smaller than the significant difference between yields for these system changes the preferred system. Therefore, a producer's ability to manage a specific tillage practice and crop rotation effectively may make a substantial difference in the preferred system. A similar parallel shift of $13.63 per acre (i.e., 4.41 bu./acre of wheat or 6.71 bu./acre of sorghum) includes the NTWF system in the efficient set.

Similar sensitivity is also demonstrated in the risk-averse interval, 0.00005 to 0.0001. If the CVWSF distribution is lowered by a parallel shift of $4,394 the NTWSF, NTWF, and CVWF systems enter the efficient set. This is equivalent to a yield reduction of 3.88 bushels per acre for wheat or 5.91 bushels per acre for sorghum.

Diversification

Stochastic dominance involves pair-wise comparisons of cdf's for specific alternatives. If the alternatives can be combined, stochastic dominance should be conducted on diversified portfolios as well. A test of whether dominance of one alternative over another implies dominance over all linear combinations of the two is found in McCarl et al. Correlation coefficients of the strategies are compared to the ratio of their standard errors. If the correlation coefficient is less than this ratio, diversification among the strategies should be addressed.

The test indicates that diversification is possible between NTWSF and NTWW. Some combination of these two systems may be feasible with the NTWSF equipment complement but not with the NTWW complement. Combinations of 10% NTWW and 90% NTWSF, 20% NTWW and 80% NTWSF, and 30% NTWW and 70% NTWSF were analyzed with the pure strategies. None of the combinations are efficient for any of the preference intervals.

Basic Commodity Program Participation

Under current government commodity program provisions, base acreage is based on cropping patterns for the previous five years. Under these provisions, a change in tillage system does not affect base acreage. However, if cropping rotations changed, the farm would not be eligible for the government program. Changing rotations from a wheat fallow base in this study would require planting more acres than are in the wheat base or planting another program crop (sorghum) which has no established base.

Given program constraints and the assumption of a wheat-fallow rotation with a wheat base of 550 acres, the farm can choose participation or nonparticipation with conventional or no-tillage operations in the wheat-fallow sequence or nonparticipation in any other tillage and crop rotation combination. The program yield (PY_{IN}) for both conventional and no-till wheat-fallow systems is the historical average of the conven

tional wheat-fallow rotation. Deficiency payments are calculated using the program yield. Even if tillage systems were changed, the deficiency payment at least in the near future would still be based on yields from conventional tillage.

Under these government program constraints, the NTWF and CVWF systems with government payments enter the efficient sets in the more risk-averse intervals (table 2, Gov't. Prog.). The CVWSF system without program payments is preferred in the less risk-averse intervals. The average net return of the CVWSF system is \$12,490 compared to the \$2,549 and \$730 for the CVWF and NTWF systems in the government program (table 1). The coefficient of variation declines for the CVWF system but increases for the NTWF system when compared to nonparticipation because of the assigned program yield. The government commodity program does not generally encourage the use of no-tillage practices for wheat fallow systems in this situation.[1] Rather, program participation encourages the use of wheat-fallow system as opposed to the somewhat more erosive conventional wheat-sorghum-fallow systems in the more risk-averse intervals (table 2).

Basic Commodity Program Participation Sensitivity Analysis

Sensitivity analyses indicate the results are very sensitive within the range of yields defined by the critical difference, cited earlier, of 3.17 bushels of wheat and 11.74 bushels of grain sorghum. In the risk preference interval 0.00001 to 0.00005, NTWSF and CVWF-G are in the efficient set if the dominant distribution (CVWSF) is lowered by a parallel shift of \$3,304. This is equivalent to a \$9.03 per acre increase in cost, a \$2.92 bushels per acre reduction in wheat yield, or a 4.45 bushels per acre reduction in sorghum yield. In the interval .00005 to .0001, where CVWSF and CVWF-G are dominant, a \$2,170 shift would include NTWSF, NTWF-G, and NTWF in the efficient set.

[1] Risk-averse managers who currently wish to maintain program base acres in a wheat-fallow rotation would prefer a no-tillage system if the program yield reflected the historical yield of the NTWF system rather than the CVWF system. When the historical NTWF yield is used, rather than the CVWF yield for the assigned program yield, and nonparticipation is ruled out, the NTWF system is dominant in the two highest risk-averse intervals.

Commodity Program with Base Acreage Change

A scenario with no restrictions on base acres and program yields is examined because no-tillage techniques in alternative crop rotations may be used to meet the erosion restrictions of a required conservation plan. The local Agricultural Stabilization and Conservation Service (ASCS) committee and state ASCS office may approve a change in base acres if the tillage and cropping system plan is approved by the Soil Conservation Service (SCS). Under this scenario, the farm manager can select the tillage system and crop rotation desired to meet the requirements of the farm's conservation plan.

Base acreage is 550 acres for crop-fallow systems, 1,100 acres for continuous crop systems and 366.7 acres for each crop in the wheat-sorghum-fallow system. The program yield (PY_{iN}) used to calculate the deficiency payment for a new tillage system and cropping practice is assumed to be based on the historical yields from the appropriate experiment station. In this case, PY_{iN} is the historical mean of the yield from each crop rotation and tillage system combination. All other requirements of the government commodity program (including set-aside acreage) remain the same.

The change in base acreage increases net return substantially in comparison to nonparticipation (table 1, Base Change). The CVWSF system with government payments is now preferred in all risk-averse intervals (table 2, Base Change). The NTWF and CVWF systems with government payments are no longer in the efficient set for the most risk-averse interval. However, this system would not be approved because the production of grain sorghum in a conventional tillage system is considered more erosive than no-tillage wheat-fallow or conventional wheat-fallow. Additional inconsistencies between crop production activities which are less erosive and commodity program benefits are addressed by Reichelderfer.

Commodity Program with Paid Land Diversion

The 1985 farm bill also contains an optional paid land diversion for feed grains. Designed to further reduce crop surpluses, this policy may reduce risk by providing a fixed payment to producers who voluntarily divert an additional 15%

of their feed grain acreage base to conservation use. Payment for the additional acres is based on the payment rate ($OPDR_{iN}$), acres diverted (OPD_{iN}), and program yield (PY_{iN}) [equation (1)].

These provisions apply to grain sorghum in this analysis. Optional diverted acres (OPD_{iN}) are 15% of the base acreage and the optional paid diversion rate ($OPDR_{iN}$) is \$1.90 per bushel. Planted acres are now equal to the acres planted under the previous situation (PA_{iN}) less the additional acres diverted (OPD_{iN}). Total set-aside acres now equal the initial set-aside acres (ARP_{iN}) plus the diverted acreage (OPD_{iN}). There is no optional paid diversion for wheat.

When these provisions are included, average net returns in table 1 for the systems including sorghum (15% diversion) are smaller than under the government program without the optional diversion (Gov't. Program); however, their variability is decreased due to the removal of price and yield variability from the additional diverted acres. Optional paid diversion reduced both the maximum loss and maximum gain. Lower net returns occur because the reduction in gross returns due to the diversion payment being lower than the average grain sorghum price exceeds the reduction in costs from diverting planted acres to set-aside acres.

A scenario allowing a change in base acreage and program yield plus the optional paid land diversion also is evaluated (table 2, Paid Land Diversion). In this scenario, the SSD-efficient strategies are conventional tillage wheat-sorghum-fallow, with the basic government program and with the additional 15% paid land diversion (CVWSF-G, CVWSF-D). Very strongly risk-averse producers would prefer the CVWSF system with the optional paid land diversion. In less strongly risk-averse intervals the basic gover ment program is preferred or indifferent to t program with the optional paid diversion. Sin this conventional tillage system has more er sive characteristics than a wheat-fallow syster the change would not be approved as part of soil conservation plan.

Tillage System Selection

The risk-efficient set of cropping rotations f each tillage method and the efficient set of t lage methods for each crop rotation are al evaluated. Under nonparticipation the whea sorghum-fallow cropping sequence is preferr in most risk-averse intervals for both the co ventional and no-tillage systems (table 3). T preferred tillage system varies by crop rotatio The no-till system is preferred for the whea fallow, continuous wheat, and continuo sorghum rotations, while the conventional t lage system is preferred for the sorghum-fallo and wheat-sorghum-fallow rotations. These r sults suggest that the conventional tillage syste is desirable when sorghum is included in a fa low cropping system.

Program participation is also evaluated l cropping rotation (table 4). Base acreage is a nual planted crop areas; 550 for crop-fallow sy tems, 1,100 for continuous systems, and 366 acres for each crop in the wheat-sorghum-fallc systems. The program yield used in calculati deficiency payments is the historical average fro the conventional tillage system for each crop r tation.

Stochastic dominance analysis indicates th the conventional tillage system including go

Table 3. Stochastic Dominance Results by Tillage System and Crop Rotation for Nonpa ticipation

Lower $R(x)$		Upper $R(x)$	Tillage Method CV	NT	Crop Rotation WF	WW	SF	SS	W
−0.00005	to	−0.00001	WSF	WSF	NT	NT	CV	NT	C
−0.00001	to	0.0	WSF	WSF	NT	NT	CV	NT	C
−0.00001	to	0.00001	WSF	WSF	NT	NT	CV	NT	C
0.0	to	0.00001	WSF	WSF	NT	NT	CV	NT	C
0.00001	to	0.00005	WSF	WSF	NT	NT	CV	NT	C
0.00005	to	0.0001	WSF	WSF	NT	NT	CV	NT	C
0.0001	to	0.001	WSF	WSF, WF	NT	NT	CV	NT	C

Note: CV is conventional tillage; NT, no-tillage; WF, wheat-fallow; WW, continuous wheat; SF, sorghum-fallow; SS, continuous sorghu WSF, wheat-sorghum-fallow. These results indicate the preferred crop rotation given that the indicated tillage system is the only opti available or the preferred tillage system given that the crop rotation is the only option possible.

Table 4. Stochastic Dominance Results by Crop Rotation with Commodity Program Participation

Lower R (x)		Upper R (x)	WF-G	WW-G	SF-G	SS-G	WSF-G	SF-G-D	SS-G-D	WSF-G-D
−0.00005	to	−0.00001	NT, CV-G	NT, NT-G	CV-G	NT, CV-G, NT-G	CV-G	CV-G	CV-G, NT, NT-G	CV-G
−0.00001	to	0.0	CV-G	CV-G, NT-G	CV-G	NT-G	CV-G	CV-G	NT-G	CV-G
−0.00001	to	0.00001	CV-G	CV-G, NT-G	CV-G	NT-G	CV-G	CV-G	NT-G	CV-G
0.0	to	0.00001	CV-G	CV-G	CV-G	NT-G	CV-G	CV-G	NT-G	CV-G
0.00001	to	0.00005	CV-G	CV-G	CV-G	CV-G, NT-G	CV-G	CV-G	CV-G, NT-G CV-D, NT-D	CV-G
0.00005	to	0.0001	CV-G	CV-G	CV-G	CV-G	CV-G	CV-G, CV-D	CV-D	CV-G, CV-D
0.0001	to	0.001	CV-G, NT-G	CV-G	CV-G	CV-G	CV-G	CV-D	CV-D	CV-D

Note: CV is conventional tillage; NT, no tillage; WF, wheat-fallow; WW, continuous wheat; SF, sorghum-fallow; SS, continuous sorghum; WSF, wheat-sorghum-fallow; -G, indicates distributions with basic government program participation; -D, indicates distributions with government program participation including paid land diversion for feed grains. These results indicate the preferred tillage system with or without the government program given that the indicated crop rotation is the only option available because of established base acres.

ernment program payments is preferred for most crop rotations. The no-tillage system is included in the most strongly risk-averse interval for the wheat-fallow rotation, and in two less risk-averse intervals for the continuous sorghum system (table 4). When these results are compared with those in table 3, government program participation tends to discourage no-tillage practices.

The impact on tillage practice selection by the commodity program with the optional paid land diversion is also evaluated for rotations including sorghum (table 4; SF-G-D, SS-G-D, and WSF-G-D). Conventional tillage is generally preferred for most crop rotations with the exception of the continuous sorghum sequence. The optional paid land diversion is generally selected in the more risk-averse intervals and the basic government program in less risk-averse intervals.

Concluding Comments

A conventional wheat-sorghum-fallow system is generally preferred by risk-averse managers when government program payments are not considered. When government commodity program provisions are included very highly risk-averse individuals prefer the no-till wheat-fallow and conventional wheat-fallow rotations. However, in less risk-averse intervals, the conventional tillage wheat-sorghum-fallow system without government program payments is preferred. These results are quite sensitive to production cost and yield changes.

Although the conservation compliance provisions of the 1985 Food Security Act have the objective of reducing soil erosion, the commodity program provisions do not encourage the use of no-tillage systems for wheat and sorghum in this region. This study finds that the commodity program assigned yield provision discourages the use of no-till practices for wheat rotations. Producers who diversify with no tillage grain sorghum would also be adversely affected by this provision. The risk reduction characteristic of the optional paid land diversion contributes to risk-averse managers preferring rotations including more erodible sorghum enterprises instead of rotations that are exclusively wheat, which has no optional paid land diversion. A change in base acres and program yield allowed by an approved conservation plan does not provide sufficient incentive for using a no-tillage system in the wheat-grain sorghum-fallow rotation.

The reader is reminded that the only behavioral attribute considered in this study is risk attitude with regard to income. Farmers have multiple farm management objectives including managing financial risk, soil conservation, and maintaining government program eligibility (institutional risk) which deserve evaluation. The current commodity program rule which restricts switching base acres to maintain program eligibility is a major factor which encourages the continued use of wheat, which is less erosive than grain sorghum, on traditional wheat-fallow farms as opposed to diversifying with a more erodible grain sorghum enterprise.

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Agricultural Production Technologies with Systematic and Stochastic Technical Change

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A production system modeling tool is developed that implements recent work on autoregressive and endogenous stochastic production technologies associated with generalized Fechner-Thurstone (GFT) optimizing functions. A GFT-class production system is used to evaluate the empirical support for technology specifications inherent in the neoclassical theoretic structure of an agricultural production region. Little likelihood support is found for zero serial correlation, elimination of systematic technology changers from the production system, strict neoclassical production technologies, Hicks-neutral technical change, or zero homogenous factor demand functions.

Key words: endogenous technology, generalized Fechner-Thurstone, primal, technical change.

Economic theory provides a rigorous and unambiguous logical structure in which to model optimizing production behavior. It identifies equivalent methodological foundations for examining behavior, implies within and cross-equation restrictions, and even suggests likely data correlations and error relationships. Nevertheless, economic theory is insufficient alone to provide unambiguous model specifications or a complete statistical foundation for examination of production technology.

In most cases where systems of partial derivative equations implied by the theory have been estimated in order to derive implications about technology, a time trend has been included as a regressor to capture information on technical change and a random error has been appended to the estimation of optimizing conditions. The continuing use of this procedure ignores a growing body of literature that calls into doubt the conventional causal interpretation of time trend parameters and the important body of literature addressing the stochastic nature of production technology that dates to work in the mid-1960s by Mundlak and Hoch and by Zellner, Kmenta, and Dreze.

In addition, continued use of conventional methods perpetuates the naive assumptions that (*a*) producers are unable to compute optimal solutions even when they know the true functional specifications of nonstochastic production technologies, and (*b*) changes in aggregate technology remain invariant to changes in exogenous economic variables. Because of rapidly changing microproduction processes and techniques, long production periods, and dependence on the vagaries of weather, it is likely that the primary uncertainty in agricultural production centers on the technology itself. Further, because of both systematic and stochastic variation of the agricultural production technology, changes in exogenous economic variables may provide incentives for producers to alter their choice of specific production techniques from among the complete set of available microproduction processes comprising the aggregate technology. The choice of microproduction processes then defines the ob-

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served production technology (as reflected in aggregate data) which is endogenous to the economic system (Mundlak and Hellinghausen, Mundlak).

In this paper, a simple model selection procedure is used to assess the likelihood support for a production model which does not restrict technical change to be invariant to changes in exogenous economic variables nor to stochastic shocks to the production system. Agricultural production behavior in the northeastern states region is analyzed using a primal behavioral model specification where technology is characterized by a generalized Fechner-Thurstone (GFT) functional form.[1] The GFT framework incorporates a parametric specification which maintains that optimization errors associated with changing technology can occur because of (*a*) stochastic variation of the production technology map, (*b*) alterations of the microproduction functions, and/or (*c*) choice among available production techniques.

Two classes of the GFT form are estimated using annual data for the period 1950–82. For each class three objectives are pursued: (*a*) Evaluate likelihood support for alternative serial correlation hypotheses on stochastic technology changers. (*b*) Evaluate the likelihood support for an empirical model of aggregate production embodied in the GFT specification of production technology relative to specific conventional production models which maintain invariance of technical change to changes in economic variables. (*c*) Evaluate both disembodied and embodied technical change hypotheses. In addition, Marshallian uncompensated factor demand elasticities are computed and analyzed for one class.

The Generalized Fechner-Thurstone Production System

Theoretical properties of GFT forms have been introduced and investigated by Basmann and by Basmann et al. (1983; 1984a, b; 1985; 1987). Additional contributions to the theoretical development of a GFT-class optimizing function in the context of production theory were presented in work by Charnes et al. (1976, 1983). Bewley and Young recently reported in th journal a GFT-class (generalized addilog) d mand system analysis of meat expenditures.

Motivation for our application of GFT-cla optimizing functions to aggregate regional a ricultural production technologies parallels many ways that of Basmann et al. (1983, 1984 1985). First, aggregate production behavior modeled within the context of the GFT fun tional class. The GFT is most general in the sen that any system of demand functions (which the result of some constrained optimization pr cess) can be derived by optimization of a fun tion defined within one of its classes. Oper tionally the GFT is a variable, random-coefficie generalized Cobb-Douglas functional form.

Second, aggregate production behavior modeled within a framework which does not r strict technical change to be invariant to chang in exogenous economic variables or stochast shocks to the production system. Price chang not only generate direct changes in chosen inp and output levels but also changes in the o served production function. The aggregate tec nology is a function of prices as well as oth state variables. Thus, as noted also by Mundla a correct interpretation of industry-level inp demand and output supply responses necess tates proper accounting for the endogenous n ture of the aggregate technology.

Third, the aggregate factor demand functio derived from the GFT production function ha the same form in arguments and parameters those derived from individual firm-level pr duction functions. Thus, the magnitude of t aggregate demand for any given factor is t arithmetic sum of magnitudes from the indivi ual producer demand functions (Basmann et a 1984a).

In addition, modeling the production tec nology in the GFT framework allows the eco omist to determine whether or not an accum lating body of evidence from observ equilibrium data supports the conventional m croeconomic assumption of independence b tween technical change and economic variable Rather than reproduce the properties of GF forms, the interested reader is directed to Ba mann et al. (1984a, b, 1985).

An Empirical Model

The aggregate production system for the nort eastern states region is modeled in a mann consistent with profit-maximizing price-taki

[1] This functional form was first proposed for indifference maps by L. L. Thurstone. In the special case of fixed technology, the GFT form reduces to a monotonically increasing function of the well-known Cobb-Douglas production function.

behavior subject to a budget constraint.[2] Assuming an aggregate output index, budget-constrained output maximization yields the same optimal solution as budget-constrained profit maximization. Let P be a vector of factor prices and let C denote expenditure on factors in a specified production period which is effectively constrained at C^*. Under the assumption that marginal products are positive for all factors, producers exhaust the aggregate budget in purchasing factors of production (i.e., $C = C^*$). It is assumed that producers select a definite equilibrium n-tuple production bundle $X = (x_1, \ldots, x_n)$ such that the choice results in maximization of a generalized Fechner-Thurstone production function for aggregate output:[3]

$$(1) \qquad F(X;\theta) = a\Pi_i x_i^{\theta_i(\gamma)},$$

subject to

$$(2) \qquad C = \Sigma_i p_i x_i,$$

where the n-tuple θ of positive-valued functions, $\theta_i(\gamma)$ $i = 1, \ldots, n$, is the parameter vector of $F(X;\theta)$.[4] For constant γ, the GFT production function is homogenous of degree $\Sigma_i\theta_i$, strongly separable and homothetic in X, and exhibits constant elasticity of substitution among elements of X equal to unity everywhere.[5]

In terms of economic behavior, elements of the argument vector X are under the producer's control, whereas elements of the parameter vector $\theta(\gamma)$ are not. The components of γ are referred to as technology changers. These are classified as (*a*) technology changers that are systematic and observable, and (*b*) technology changers that are stochastic and nonobservable. It is assumed that the marginal products derived from $F(X;\theta)$ can be expressed as a product of a systematic function and a stochastic element. A component γ_k of γ is said to be a technology changer with respect to $F(X;\theta)$ if, and only if, (*a*) the economic agent cannot quickly adjust γ_k to its optimal level when the exogenous prices and/or budget constraint change, or (*b*) a change in γ_k causes a change in at least one marginal rate of technical substitution for at least one point X_0 in the domain of $F(X;\theta)$.[6]

Family labor illustrates a systematic parameter in the vector γ. Few off-farm work opportunities are prevalent in many rural areas. Thus, family farm labor tends to adjust slowly toward optimal levels (e.g., Tweeten, pp. 175–76; Vasavada and Chambers). In addition, births and deaths may affect the slopes and shapes of the technology map of $F(X;\theta)$ by altering the composition of family farm laborers. Any variable that affects the production technology map in similar ways is called a technology changer.

A necessary consequence of budget-constrained output maximization is that the first partials of the following lagrangian with respect to variable inputs and the Lagrange multiplier equal zero:

$$(3) \qquad L = a\Pi_i x_i^{\theta_i(\gamma)} + \lambda(C - \Sigma_i p_i x_i),$$

where λ is the Lagrange multiplier. The $n + 1$ first-order conditions are

$$(4) \qquad \partial L/\partial x_i = \theta_i(\gamma)F(X;\theta)/x_i - \lambda p_i = 0, \quad i = 1, \ldots, n,$$

$$(5) \qquad \partial L/\partial \lambda = C - \Sigma_i p_i x_i = 0.$$

From (4)

$$(6) \qquad p_i x_i / p_j x_j \equiv S_i/S_j = \theta_i(\gamma)/\theta_j(\gamma),$$

where S_i is the ith input's share of cost. Note that, in equilibrium, the ratio of expenditures on factor i to factor j is equal to the ratio of GFT parameters. Solving (6) for p_i,

$$(7) \qquad p_i = [\theta_i(\gamma)/\theta_j(\gamma)]p_j x_j x_i,$$

and inserting (7) into (5) yields

$$(8) \qquad C = \Sigma_i[\theta_i(\gamma)/\theta_j(\gamma)](p_j x_j/x_i)/x_i = [p_j x_j/\theta_j(\gamma)]\Sigma_i\theta_i(\gamma).$$

Solving (8) for x_j yields the expenditure-constant factor demand functions,

[2] Farm lenders determine creditworthiness of individual borrowers based largely on expectations for repayment. These expectations can be expressed in the form of leverage limitations and/or borrower controls as well as interest rates. The combination of these manifestations suggests an aggregate limit on credit availability. In support of this maintained hypothesis, it is noted that an empirical test of budget-constrained profit maximization in U.S. agriculture was not rejected by Lee and Chambers for the period 1947–80. Unconstrained profit maximization, however, was rejected.

[3] This form is a special case of the one used by Basmann et al. (1984b), that restricts the origin of reference for the production function to (0, ..., 0). This function is also a special case of the generalized power production function (de Janvry), $F = a\Pi_i x_i^{\theta_i} e^{g(X)}$, with $g(X) = 0$ and generalized such that θ_i is a function of technology changers γ.

[4] The notational device of separating the arguments of a function from its parameters by a semicolon will be invoked throughout this paper.

[5] Since γ varies across time periods, these properties, which are implied by a Cobb-Douglas production function, hold only within a single production period. Thus, they are temporally local properties.

[6] By this definition of a technology changer, homothetic shifts in the technology map (i.e., neutral technical changes) are indistinguishable from no shift in the technology map. While this omission may appear important, empirical tests of technical change in U.S. agriculture have quite consistently found it to be non-neutral (e.g., see Antle 1984, Binswanger, Weaver).

(9) $$x_j = [\theta_j(\gamma)/\theta(\gamma)]C/p_j,$$

where $\theta(\gamma) = \Sigma_i\theta_i(\gamma)$.

Factor demand functions (9) depend only on the parameters of the specified GFT production function, $F(X;\theta)$, and the parameters of the budget constraint (2). Demand functions are homogenous of degree zero when elements of the technology changer vector γ are independent of budget constraint parameters. However, if changes in budget constraint parameters influence the shape of the technology map (as permitted in the empirical application), zero homogeneity is not implied. Generalization of GFT-rationalized demand systems is easily observed by noting that demand functions (9) have the form of the generalized demand system investigated by Seo. Because every system of demand functions which satisfies the ordinary linear budget constraint can be represented in the generalized form (Seo), it follows that every system of demand functions can be rationalized by some GFT-class function (Basmann et al. 1985, pp. 19–20).

Two GFT classes of production functions are investigated in this paper. Both are variations of the Cobb-Douglas functional form with variable, random coefficients. The first is the constant elasticity of marginal rate of technical substitution form (GFT-CEMRTS), and the second is the constant ratio of elasticity of substitution form (GFT-CRES). These classes were chosen for several reasons: (*a*) they provide a framework in which likelihood support among alternative serial correlation hypotheses on stochastic technology changers is easily investigated; (*b*) they permit easy evaluation of likelihood support for a model of technical change which is not based solely on information contained in parameters of time trend variables; (*c*) they do not impose arbitrary restrictions on the demand system at a point; (*d*) they provide an empirical framework for assessing the likelihood support for an endogenous technical change model relative to established conventional cases of production functions which have technology images within the respective GFT classes;[7] and (*e*) they permit evaluation of Hicksian technical bias and factor demand elasticities within the conte of a theoretical model where systematic and stc chastic technical change is allowed to warp th technology map.

[7] Maximum likelihood methods necessitate the complete specification of a parent population sample density function. Even if the stochastic element in the parameter vector $\theta(\gamma)$ is normally distributed, it is not practical to treat the whole class of parent populations as a grand maintained hypothesis. We have therefore chosen to assess subclasses of the whole GFT-class sequentially. Initially, we have focused on two maintained hypotheses that permit likelihood ratio tests of some widely recognized forms of conventional production functions.

GFT-CEMRTS Form

The GFT-CEMRTS form specifies that the $\theta($ parameters of (1) are characterized as follows

(10) $$\theta_i^*(C, P, Z) = \beta_i C^{w_{io}} \Pi_j p_j^{w_{ij}} \Pi_q z_q^{w_{iq}}, \quad i, j = 1, \ldots, n;\ q = 1, \ldots, m$$

(11) $$\theta_i = \theta_i^* e^{u_i},\ i = 1, \ldots, n,$$

where $u = \{u_1, \ldots, u_n\}$ is a latent random vectc with a mean of zero and a finite positive definit variance matrix, Ω_o. The vector u characterize a vector of stochastic technology changers. I addition, the serial covariance matrices Ω_s, $s =$ 1, 2, ..., n, may represent persistence of effect of stochastic changes in technology. The vectc Z characterizes systematic technology changer which are not parameters of the expenditur constraint and may include demographic infoi mation, weather variables, lagged values of and P, and other exogenous variables.

The estimation equations for the empirica model are characterized by

(12) $$\theta_i/\theta_k \equiv S_i/S_k = \beta_i C^{w_{io}} \Pi_j p_j^{w_{ij}} \Pi_q z_q^{w_{iq}} e^{u_i} / \beta_k C^{w_{ko}} \Pi_j p_j^{w_{kj}} \Pi_q z_q^{w_{kq}} e^{u_k}$$

Taking natural logarithms of (12) yields the − 1 estimation equations for the GFT-CEMRT model.

(13) $$\ln(S_i/S_k) = \ln(\beta_i/\beta_k) + w_{io}^k\ln(C) + \Sigma_j w_{ij}^k \ln(p_j) + \Sigma_q w_{iq}^k \ln(z_q) + \xi_i^k,\ i = 1, \ldots, n,\ i \neq k,$$

where $w_{io}^k = w_{io} - w_{ko}$, $w_{ij}^k = w_{ij} - w_{kj}$, $w_{iq}^k =$ $w_{iq} - w_{kq}$, and $\xi_i^k = u_i - u_k$.

Marshallian uncompensated factor deman elasticities with respect to changes in prices P the expenditure constraint C, and technolog changers Z are of the following form.

Price elasticity:

(14) $$\epsilon_{ij} = \Sigma_k(\theta_k/\theta)w_{ij}^k - \delta_{ij},$$

where

(15) $$\delta_{ij} = \begin{cases} 1 & \text{for } i = j, \\ 0 & \text{otherwise.} \end{cases}$$

Expenditure elasticity:

(16) $$\epsilon_{io} = \Sigma_k(\theta_k/\theta)w_{io}^k + 1.$$

Elasticity of factor demand with respect to a change is an element of the systematic technology changer, z_q:

$$(17) \qquad \epsilon_{iq} = \Sigma_k(\theta_k/\theta)w^k_{iq}.$$

The GFT model provides straightforward primal-based measurements of technical change biases. The estimated parameters measure the sensitivity of the slope of the isoquant to changes in technology changers at a given point on the aggregate expansion path.[8] That is, the elasticities of the marginal rates of technical substitution of factor k for factor i, with respect to expenditure (C), prices (P), and other systematic technology changers, (Z), are represented by the estimated parameters w^k_{io}, w^k_{ij}, w^k_{iq}, respectively, at a point in input space.

GFT-CRES Form

The GFT-CRES form specifies that the $\theta(\gamma)$ parameters of (1) are characterized as follows:

$$(18) \qquad \theta^*_i(C, P, Z) = \beta_i \Pi_j [x^*_j(C, P, Z)]^{b_{ij}} \Pi_q z_q^{b_{iq}}, \quad i, j = 1, \ldots, n; q = 1, \ldots, m,$$

$$(19) \qquad \theta_i = \theta^*_i e^{u_i}.$$

In equilibrium, $x_j = x^*_j(C, P, Z), j = 1, \ldots, n$, which are unknown functions. Since θ^*_i is functionally dependent only on (C, P, Z), satisfaction of the first-order conditions implies estimation equations characterized by

$$(20) \qquad \theta_i/\theta_k \equiv S_i/S_k = (\beta_i/\beta_k)\Pi_j(x_j)^{b_{ij}-b_{kj}}\pi_q z_q^{b_{iq}-b_{kq}} e^{u_i-u_k}.$$

Taking logarithms of (20) yields the $n-1$ estimation equations for the GFT-CRES model.

$$(21) \qquad \ln(S_i/S_k) = \ln(\beta_i/\beta_k) + \Sigma_j b^k_{ij}\ln(x_j) + \Sigma_q b^k_{iq}\ln(z_q) + \xi^k_i, \; i = 1, \ldots, n, \; i \neq k,$$

where $b^k_{ij} = b_{ij} - b_{kj}$, $b^k_{iq} = b_{iq} - b_{kq}$, and $\xi^k_i = u_i - u_k$.

As with the GFT-CEMRTS form, these estimated parameters provide a primal measure of bias in technical change. However, explicit forms of the GFT-CRES demand functions are not tractable. Therefore, demand elasticities for this class are not calculated.

Econometric Estimation

The stochastic variables, u_i, are assumed to affect demand functions (9) solely through the parameters $\theta(\gamma)$. Consequently, random variables are not "tacked-on" to demand functions. These errors in the estimation equations are caused by stochastic changes in technology not anticipated by decision makers rather than to errors in optimizing behavior. However, the equations estimated are not perfect fits of the actual optimizing behavior because of the presence of unobserved causal variables which change over the data period and to measurement errors on observed variables.

For this study each of the random elements ξ^k_i given in equations (13) and (21) is assumed to follow a second-order autoregressive schema. The random element ξ^k_i in each estimation equation takes the form.

$$(22) \qquad \xi^k_{i,t+2} - \Phi_{i,1}\xi^k_{i,t+1} + \Phi_{i,2}\xi^k_{i,t} = \epsilon_{i,t+2}, \forall i, k,$$

where $E[\epsilon_t] = 0$, $E[\epsilon_t\epsilon_s] = 0$ for $t \neq s$, and $E[\epsilon^2_t] = \sigma^2_\epsilon$.

Basmann's theory on the serial correlation of stochastic taste changes modeled in the context of GFT forms provides a methodology for reducing the number of independent parameters associated with estimation of an autoregressive production system. For a second-order autoregressive schema, the autocovariance matrices are determined by the variance matrix and the two AR(2) autocorrelation coefficients, $\Phi_{i,1}$ and $\Phi_{i,2}$. Minimal sufficient statistics for each empirical model were estimated using the general linear model (GLM).[9] The dependent variable vector and the matrix of independent variables were transformed according to a maintained AR(2) hypothesis on $\Phi_{i,1}$ and $\Phi_{i,2}$ values over the stability domain implied by the Routhian conditions (Kenkle). The GLS estimators were then obtained by applying the method of least squares to the transformed model (Judge et al.). For restricted models with cross-equation restrictions and/or where the regressors were not the same in all equations, i.e., (24)–(30), the seemingly unrelated (SUR) estimation procedure (Zellner)

[8] Note from (6) and (13) that $w^k_{i,time}$, which equals $\partial\ln(F_i/F_k)/\partial\ln(time)$ in equilibrium, provides an equivalent qualitative measure of the technical change bias parameter B_{ik} presented by Antle and Capalbo in their equation (13) in chapter 2. The technical bias with respect to any of the exogenous variables can be computed in like manner (Antle 1988) from the estimated parameters.

[9] The minimal sufficient statistics are the parameter estimates and the variance-covariance matrix associated with the estimated model (Mood, Graybill, and Boes).

was employed to obtain parameter estimates for the system.

Data

Each model was estimated using annual agricultural production data for the northeastern states rėgion which includes the eleven states Connecticut, Delaware, Massachusetts, Maryland, Maine, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. The data were constructed by Fawson and Gottret and represent a comprehensive divisia index characterization of both prices and quantities of production aggregates from 1950 to 1982. Variables included prices (P) and quantities (X) of six variable factors: hired labor, machinery, energy, fertilizer and pesticides (chemicals), marketing and processing services for feed, seed, and livestock (FSL), and other materials. They also included total expenditure on these variable factors (C) and seven systematic technology changers (Z): year, real estate quantity, family labor quantity, sample standard deviation of monthly average temperatures over the year, sample mean of monthly average temperatures for the year, sample standard deviation of monthly precipitation over the year, and sample mean of monthly precipitation for the year. Using these data, a five-equation system, (13) or (21), was estimated for each GFT-class model investigated with materials designated as the *numèraire* factor.[10] With a single output index and a binding budget constraint, the optimal solution is not dependent on output price. Thus, output price does not appear as one of the exogenous price variables in the estimation equations.

Empirical Results

In this section, likelihood ratio tests (Mood, Graybill, and Boes; Graybill) are conducted and reported: first, to determine likelihood support for alternative serial correlation hypotheses on stochastic technology changers; second, to investigate disembodied and embodied technical change hypotheses; and third, to evaluate the likelihood support for an endogenous technical change model embodied in the GFT specification relative to the case in which technical change is maintained invariant to changes in economic variables. The testing procedure is based on evaluation of the likelihood support for the minimal sufficient statistics associated with a given model specification. Hicksian technical bias is investigated by computing primal cost-share-weighted summary measures of the sensitivity of marginal rates of technical substitution to changes in technology changing variables. Marshallian uncompensated factor demand elasticities (Lee and Chambers, p. 864) are then computed, and mean values of the distribution of elasticities are reported and analyzed for the GFT-CEMRTS model.

Determination of Serial Correlation

A grid search method was utilized to evaluate the likelihood support for 138 two-tuple sets of autocorrelation parameters $\Phi_{i,1}$ and $\Phi_{i,2}$ specified to provide extensive coverage within the stability triangle of a second-order autoregressive schema. The likelihood support for a given AR(2) hypothesis within a model class was assessed by examining the ratio of the likelihood function for a specific AR(2) two-tuple hypothesis set relative to the maximum value of the likelihood function over all 138 AR(2) two-tuple hypothesis sets which were specified. A three-dimensional graph of the relative likelihood support is presented in figure 1 for the GFT-CEMRTS class and in figure 2 for the GFT-CRES class, where Φ_1^*, Φ_2^* denotes the AR(2) parameters which generated the maximum likelihood support over the stability region. Examination of the figures reveals little likelihood support for the hypothesis of zero serial correlation.

Subsequent hypothesis testing was limited to those AR(2) hypotheses for which the value of the likelihood function (given the maintained hypotheses about the AR(2) process) was within 70% of the maximum value of the likelihood function evaluated over the population of 138 two-tuple AR(2) hypothesis sets. For the GFT-CEMRTS class, this heuristic indicated seventeen AR(2) hypotheses which would be used for subsequent tests with the maximum value of the likelihood function at $\Phi_1 = -0.40$ and $\Phi_2 = 0.90$. For the GFT-CRES model, we considered a set of ten AR(2) hypotheses for further investigation with the maximum value of the likelihood function occurring at $\Phi_1 = 0.00$ and $\Phi_2 =$

[10] Real estate and family labor could appropriately be regarded as decision variables. However, good price series are not available for either input in this region, they are frequently regarded as quasi-fixed inputs in economic analysis, and they also affect choice among microproduction processes. Consequently, they are included along with weather variables and year as systematic technology changers.

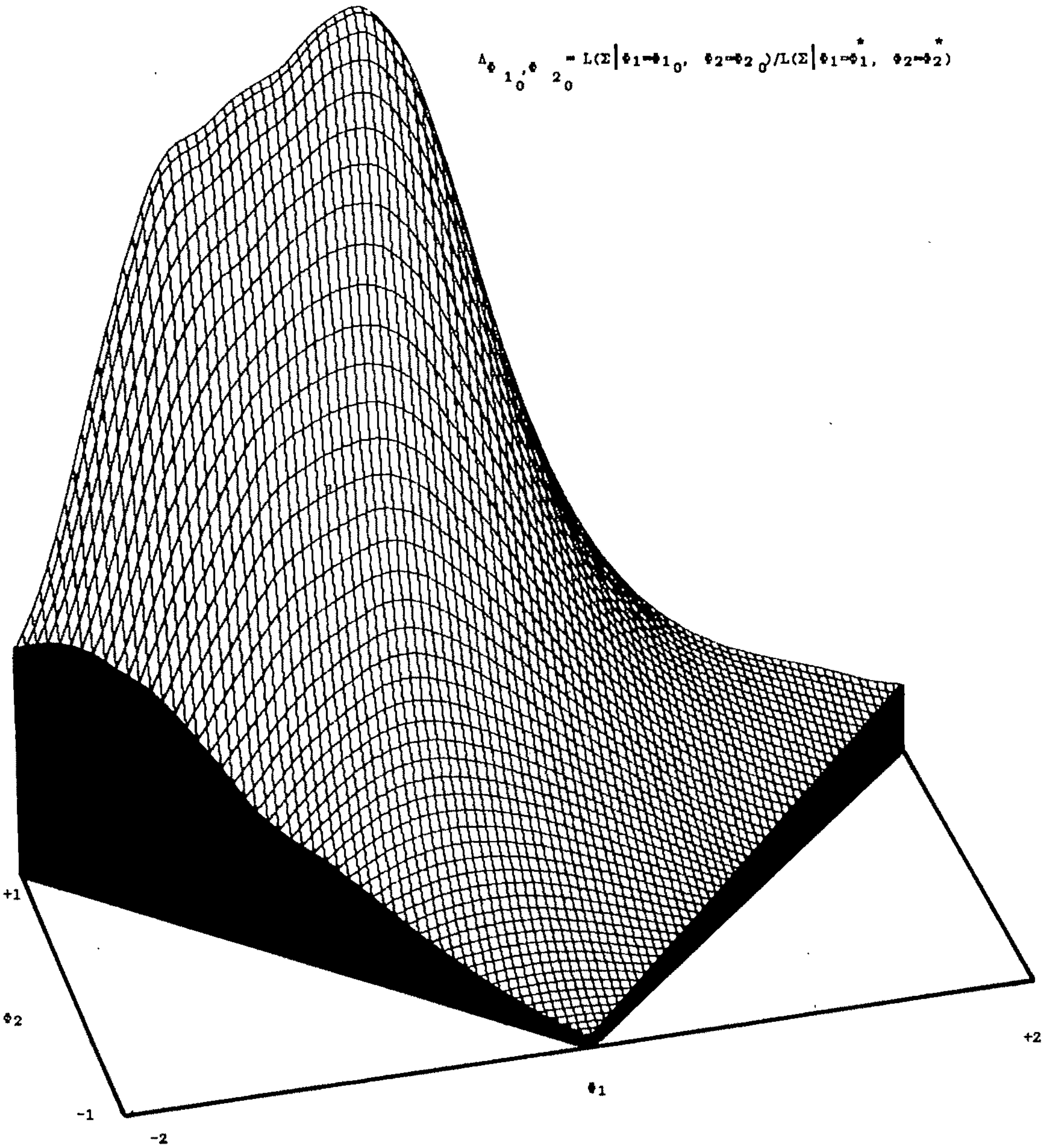

Figure 1. Likelihood ratio support for AR(2) hypotheses within the GFT-CEMRTS class

0.90. Parameter estimates for equations evaluated at the maximum AR(2) hypothesis are presented in tables 1 and 2, respectively.

Model Specification (Technology Change) Tests

Several hypotheses restricting the set of systematic technology changers were tested to determine whether production can be modeled legitimately with a more parsimonious GFT-class functional form. Hypothesis tests between restricted and unrestricted models within the specified GFT class were performed using a likelihood ratio test statistic:

$$(23) \quad \lambda_{\Phi_1,\Phi_2} = L(\text{restricted under } H_0|\Phi_1 = \Phi_{1(0)}, \Phi_2 = \Phi_{2(0)})/L(\text{unrestricted}|\Phi_1 = \Phi_{1(0)}, \Phi_2 = \Phi_{2(0)}),$$

where $\Phi_{K(0)}$ is the maintained serial correlation parameter value. A generalized likelihood ratio

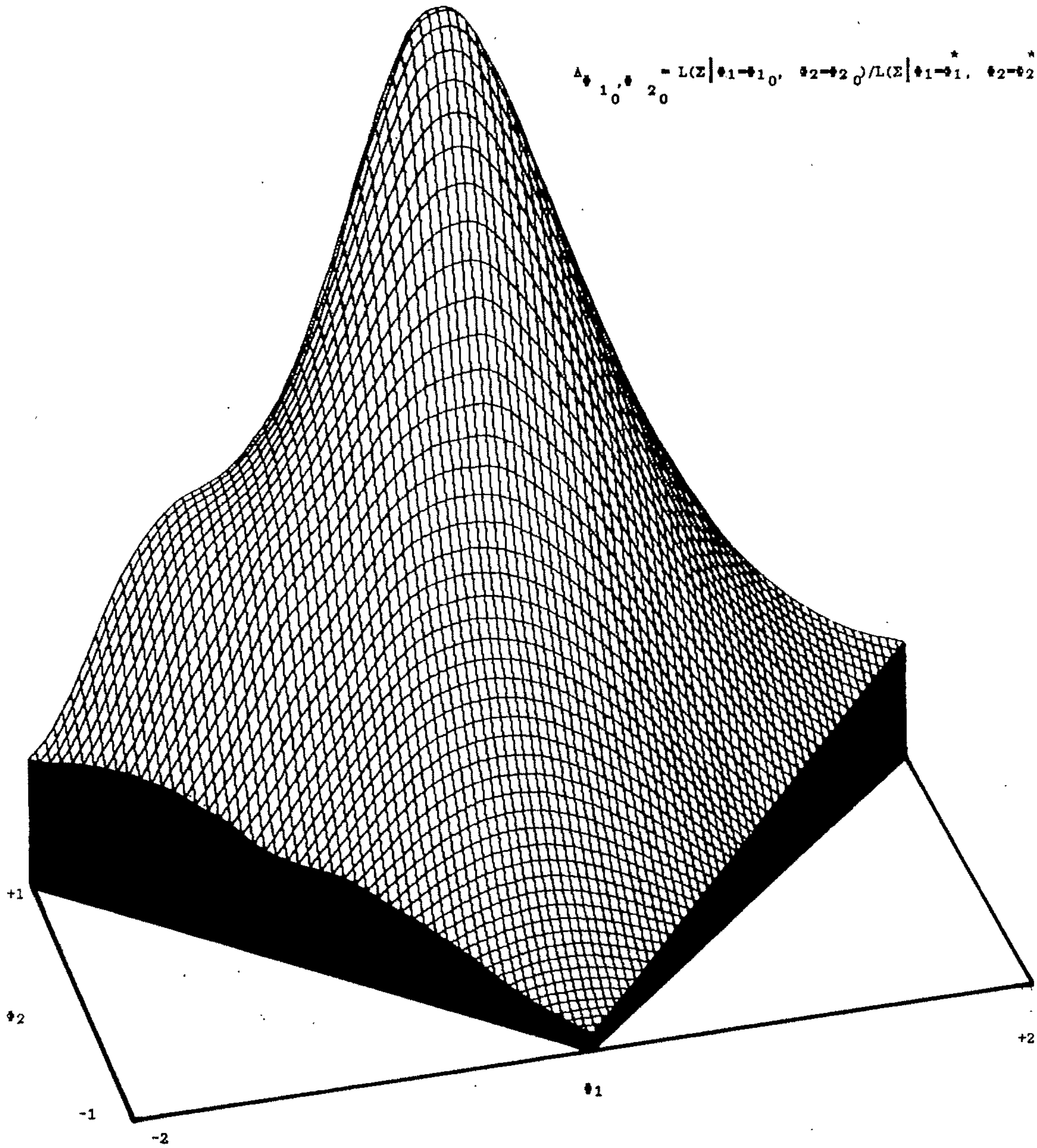

Figure 2. Likelihood ratio support for AR(2) hypotheses within the GFT-CRES class

test was defined as follows: Reject H_0 if, and only if, $-2\ \ln(\lambda_{\Phi_1,\Phi_2}) > \chi^2_{(1-\alpha)}(r)$, where $\chi^2_{(1-\alpha)}(r)$ is the $(1-\alpha)$ quantile of the chi-square distribution with r degrees of freedom. The critical bound was set to be the .95 quantile of the chi-square distribution.

Null hypotheses associated with the restricted models investigated for both GFT classes are presented in table 3. The associated likelihood ratio test statistics evaluated over the restricted set of AR(2) parameters are presented in table 4 for the GFT-CEMRTS class and in table 5 for the GFT-CRES class.

One of the important reasons for selecting a GFT-class function was to model technical progress without strict reliance on time trend variables. Likelihood ratio test statistics for the GFT-CEMRTS-class systematic technology tests indicated no support for eliminating the time trend variable or the standard deviation of the two weather variables as independent technical change variables in the production model. In addition

Table 1. Parameter Estimates for GFT-CEMRTS System, $\Phi_1 = -0.40$, $\Phi_2 = 0.90$

Exogenous Variable	Equation: Hired Labor	Machinery	Energy	Chemicals	Feed, Seed, & Livestock
Intercept	15.241	6.152	−35.555	20.771	21.789
	(.1161)[a]	(.2697)	(.0011)	(.0407)	(.0181)
$P_{Hired\ labor}$	1.065	−0.082	−0.567	0.205	−0.191
	(.0001)	(.3095)	(.0005)	(.1527)	(.1353)
$P_{Machinery}$	1.852	1.071	0.228	0.411	0.272
	(.0002)	(.0003)	(.5760)	(.3339)	(.4696)
P_{Energy}	0.052	−0.410	−2.725	−0.952	−0.395
	(.8997)	(.0995)	(.0001)	(.0328)	(.2954)
$P_{Chemicals}$	0.594	−0.218	0.019	0.720	−0.329
	(.0043)	(.0554)	(.9186)	(.0011)	(.0623)
$P_{F.S.L.}$	1.325	−0.070	−2.529	0.317	1.170
	(.0001)	(.6471)	(.0001)	(.2444)	(.0001)
$P_{Materials}$	−1.551	0.028	2.983	1.045	0.415
	(.0255)	(.9404)	(.0002)	(.1256)	(.4821)
Real estate	0.925	−0.989	−0.748	−0.386	−0.826
	(.1515)	(.0135)	(.2364)	(.5483)	(.1578)
Family labor	0.829	0.420	−0.185	0.401	0.209
	(.0003)	(.0012)	(.3291)	(.0491)	(.2318)
$\sigma_{Temperature}$	−0.170	0.159	0.446	−0.221	−0.366
	(.5690)	(.3641)	(.1406)	(.4687)	(.1853)
$Mean_{Temperature}$	−0.786	−0.440	−1.462	−1.209	−0.303
	(.2037)	(.2235)	(.0232)	(.0625)	(.5822)
$\sigma_{Precipitation}$	−0.009	−0.019	−0.072	−0.006	−0.036
	(.8508)	(.5014)	(.1401)	(.9064)	(.4114)
$Mean_{Precipitation}$	−0.230	−0.082	−0.391	−0.261	−0.223
	(.0544)	(.2249)	(.0023)	(.0341)	(.0409)
Time	−0.049	−0.031	−0.114	0.037	−0.038
	(.2998)	(.2682)	(.0216)	(.4430)	(.3698)
Total cost	−2.293	0.200	3.365	−1.045	−0.628
	(.0001)	(.3773)	(.0001)	(.0143)	(.0837)

[a] Numbers in parentheses are *P*-values associated with a two-tailed *t*-test for the null hypothesis that the parameter is zero. The endogenous variable in each equation was the logarithm of the ratio of cost shares of the specified input and materials.

other systematic technology tests indicated no likelihood support for eliminating the set of systematic technology changers which are not parameters of the budget constraint or the set which are parameters of the budget constraint.

Likelihood ratio test statistics for hypotheses which restrict the set of systematic technology changers in the GFT-CRES class were consistent with those for the GFT-CEMRTS class. There was no likelihood support for eliminating the trend variable or the standard deviation of either weather variable. Neither was there likelihood support for eliminating the other sets of systematic technology changers.

Functional Form Tests

The ability of the GFT-class production function to provide a foundation for testing whether technical change is endogenous to the production system is based on the concept of observational equivalence between conventional production technologies and images of those technologies which are nested within a GFT class. This section establishes the foundation for empirical refutation of the conventional hypotheses by examining seven cases of production functions which express independence between technical change and economic variables associated with the budget constraint. These cases were chosen because of their historical importance in the applied literature and their simplicity in demonstrating the tests made possible within the GFT modeling framework. Although not presented here, more complex second-order functions which have production technology images nested within the GFT class can also be tested.

The alternative conventional functional specifications for the system of equations ($i = 1, \ldots, n$, $i \neq k$) which have technology images within the GFT-CEMRTS and GFT-CRES classes are as follows:

Table 2. Parameter Estimates for GFT-CRES System, $\Phi_1 = 0.00$, $\Phi_2 = 0.90$

Exogenous Variable	Equation: Hired Labor	Machinery	Energy	Chemicals	Feed, Seed & Livestock
Intercept	14.659	3.773	−20.330	19.877	7.213
	(.1381)[a]	(.3674)	(.0003)	(.0059)	(.5185)
$x_{Hired\ labor}$	0.787	0.042	0.095	0.468	0.551
	(.0006)	(.6203)	(.3221)	(.0020)	(.0233)
$x_{Machinery}$	−0.384	0.835	0.389	−0.533	−0.163
	(.3562)	(.0001)	(.0632)	(.0679)	(.7336)
x_{Energy}	−0.242	0.010	0.810	0.219	−0.031
	(.1221)	(.8782)	(.0001)	(.0436)	(.8584)
$x_{Chemicals}$	1.346	0.097	−0.014	0.381	0.814
	(.0031)	(.5766)	(.9440)	(.1739)	(.0929)
$x_{F,S,L}$	−1.265	0.169	0.871	−0.437	0.195
	(.0149)	(.4180)	(.0012)	(.1888)	(.7255)
$x_{Materials}$	0.053	−0.823	−0.845	−0.516	−0.555
	(.8791)	(.0001)	(.0001)	(.0406)	(.1825)
Real estate	−1.439	−0.761	0.279	−1.290	−1.235
	(.0535)	(.0207)	(.4211)	(.0135)	(.1436)
Family labor	−0.078	0.090	−0.093	0.296	−0.121
	(.7308)	(.3654)	(.4037)	(.0673)	(.6473)
$\sigma_{Temperature}$	0.174	0.442	0.284	−0.591	−0.339
	(.5552)	(.0022)	(.0585)	(.0073)	(.3262)
$Mean_{Temperature}$	0.997	−0.171	−0.556	0.428	0.934
	(.1334)	(.5410)	(.0874)	(.3334)	(.2200)
$\sigma_{Precipitation}$	−0.0619	−0.028	−0.015	0.016	−0.050
	(.2819)	(.2615)	(.5820)	(.6689)	(.4417)
$Mean_{Precipitation}$	0.007	−0.006	−0.110	−0.048	0.065
	(.9598)	(.9208)	(.1126)	(.6099)	(.6823)
Time	−0.109	0.037	0.066	−0.013	−0.302
	(.0788)	(.1630)	(.0325)	(.7504)	(.0003)

[a] Numbers in parentheses are P-values associated with a two-tailed t-test for the null hypothesis that the parameters in zero. The endogenous variable in each equation was the logarithm of the ratio of cost shares of the specified input and materials.

Table 3. Restrictions for Alternative Technology and Functional Form Tests

Hypothesis	Null Hypothesis	Degrees of Freedom
Systematic Technology Changers		
GFT-CEMRTS Class:		
One	$Time = 0$[a]	5
Two	$\sigma_{PREC} = 0$	5
Three	$\sigma_{TEMP} = 0$	5
Four	$w^k_{iq} = 0\ \forall i, q$	35
Five	$w^k_{ij} = 0\ \forall i, j,\ w^k_{io} = 0\ \forall_i$	35
GFT-CRES Class:		
One	$Time = 0$	5
Two	$\sigma_{PREC} = 0$	5
Three	$\sigma_{TEMP} = 0$	5
Four	$b^k_{ij} = 0\ \forall i, j$	30
Five	$b^k_{iq} = 0\ \forall i, q$	35
Functional Forms with Technology Images in the GFT Class		
GFT-CEMRTS Class:		
Leontief	$w^k_{io} = 0\ \forall i,\ w^k_{ij} = 0\ \forall j \neq i, k,\ w^k_{ik} + w^k_{ii} = 0\ \forall i,$ $w^k_{ii} = 1\ \forall i$	35
Relaxed CES	$w^k_{io} = 0\ \forall i,\ w^k_{ij} = 0\ \forall j \neq i, k,\ w^k_{ik} = w^k_{jk}\ \forall i, j \neq k$	29
CES	$w^k_{io} = 0\ \forall i,\ w^k_{ij} = 0\ \forall j \neq i, k,\ w^k_{ii} + w^k_{ik} = 0\ \forall i$	30
Leser-Houthakker	$w^k_{ij} = 0\ \forall j \neq i, k,\ w^k_{ik} = w^k_{jk}\ \forall i, j \neq k,\ w^k_{io} + w^k_{ii} + w^k_{ik} = 0\ \forall i$	29
GFT-CRES Class:		
Relaxed CRES	$b^k_{ij} = 0\ \forall j \neq i, k$	20
Strict CRES	$b^k_{ij} = 0\ \forall j \neq i, k,\ b^k_{ik} = b^k_{jk},\ \forall i, j \neq k$	24

[a] H_o: *Time* = 0 implies the respective parameter on the time variable is restricted to be zero under the null hypothesis.

Table 4. Chi-Square Statistics for Likelihood Ratio Hypothesis Tests on Systematic Technology Changers and Functional Forms within the GFT-CEMRTS Class

		Technology Changer Hypotheses					Functional Form Hypotheses			
Φ_1	Φ_2	One	Two	Three	Four	Five	Leontief	Relaxed CES	CES	Leser-Houthakker
−0.40	0.70	42.61	11.70	32.48	206.53	459.67	421.46	255.03	344.01	325.48
		(.001)	(.039)	(.001)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)
−0.60	0.70	41.12	10.76	27.72	217.24	475.65	432.79	264.65	361.56	341.72
		(.001)	(.056)	(.001)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)
−0.80	0.70	39.72	15.18	22.37	234.34	496.29	448.23	277.37	384.77	362.10
		(.001)	(.010)	(.001)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)
−1.10	0.70	41.06	31.09	19.17	272.25	534.06	482.70	303.22	430.20	402.81
		(.001)	(.001)	(.002)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)
−1.30	0.70	47.93	38.98	27.74	294.76	555.41	504.17	320.47	458.34	423.75
		(.001)	(.001)	(.001)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)
−0.20	0.90	50.81	25.85	42.71	220.39	472.49	436.79	268.30	354.49	334.56
		(.001)	(.001)	(.001)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)
−0.40	0.90 (max)	51.58	18.24	41.19	228.21	483.62	448.27	276.99	365.89	347.28
		(.001)	(.003)	(.001)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)
−0.60	0.90	47.36	12.30	35.94	233.84	494.84	455.24	282.73	379.00	359.02
		(.001)	(.031)	(.001)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)
−0.90	0.90	43.99	37.08	21.26	300.14	567.16	514.58	330.25	479.35	441.54
		(.001)	(.001)	(.001)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)
−1.25	0.90	42.52	15.84	27.65	256.63	524.23	475.64	301.31	419.19	390.74
		(.001)	(.007)	(.001)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)
−0.20	0.95	52.62	28.54	44.55	224.68	478.04	441.95	272.91	359.66	339.56
		(.001)	(.001)	(.001)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)
−0.40	0.95	53.43	20.19	42.89	231.99	488.44	453.00	281.06	370.21	351.67
		(.001)	(.001)	(.001)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)
−0.60	0.95	48.76	12.98	37.59	236.61	498.55	459.19	285.95	382.03	362.33
		(.001)	(.024)	(.001)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)
−0.80	0.95	44.44	12.72	32.03	248.46	515.66	470.12	296.15	405.56	378.88
		(.001)	(.026)	(.001)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)
−1.00	0.95	42.57	18.89	27.22	269.82	539.51	488.94	313.18	442.26	412.54
		(.001)	(.002)	(.001)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)
−1.20	0.95	43.32	31.35	22.67	294.97	564.11	511.34	329.26	478.63	443.54
		(.001)	(.001)	(.001)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)
−1.40	0.95	47.49	44.53	23.47	315.09	582.35	529.64	342.35	497.92	453.11
		(.001)	(.001)	(.001)	(.001)	(.001)	(.0001)	(.0001)	(.0001)	(.0001)

Note: approximate area in the upper tail of a chi-square distribution with r degrees of freedom are in parentheses.

Table 5. Chi-Square Statistics for Likelihood Ratio Hypothesis Tests on Systematic Technology Changers and Functional Forms within the GFT-CRES Class

		Technology Changer Hypotheses					Functional Form Hypotheses	
Φ_1	Φ_2	One	Two	Three	Four	Five	Strict CRES	Relaxed CRES
0.20	0.70	40.44	21.69	26.39	345.44	158.65	202.54	176.00
		(.001)[a]	(.001)	(.001)	(.001)	(.001)	(.0001)	(.0001)
0.00	0.70	47.28	21.39	29.93	354.91	172.98	216.17	187.02
		(.001)	(.001)	(.001)	(.001)	(.001)	(.0001)	(.0001)
−0.20	0.70	49.35	16.83	29.74	360.35	181.99	221.48	187.62.
		(.001)	(.004)	(.001)	(.001)	(.001)	(.0001)	(.0001)
0.20	0.90	47.31	29.52	33.14	370.78	179.46	235.62	205.04
		(.001)	(.001)	(.001)	(.001)	(.001)	(.0001)	(.0001)
0.00	0.90	57.92	32.07	37.47	381.06	195.97	253.58	221.43
		(.001)	(.001)	(.001)	(.001)	(.001)	(.0001)	(.0001)
−0.20	0.90	61.55	27.32	35.59	384.73	204.41	258.63	221.95
		(.001)	(.001)	(.001)	(.001)	(.001)	(.0001)	(.0001)
−0.40	0.90	55.69	17.34	31.33	382.35	203.50	249.56	206.47
		(.001)	(.004)	(.001)	(.001)	(.001)	(.0001)	(.0001)
0.20	0.95	48.44	31.14	34.48	375.91	183.42	242.52	211.13
		(.001)	(.001)	(.001)	(.001)	(.001)	(.0001)	(.0001)
0.00	0.95	59.70	34.35	38.98	386.32	200.14	260.93	228.27
		(.001)	(.001)	(.001)	(.001)	(.001)	(.0001)	(.0001)
−0.20	0.95	63.66	29.73	36.75	389.69	208.34	265.66	228.56
		(.001)	(.001)	(.001)	(.001)	(.001)	(.0001)	(.0001)

[a] Approximate area in the upper tail of a chi-square distribution with r degrees of freedom are in parentheses.

Cobb-Douglas: (GFT-CEMRTS Class)

$$(24)\quad \ln(S_i/S_k) = \ln(\beta_i/\beta_k) + \Sigma_q w^k_{iq} \ln(z_q) + \xi^k_i.$$

Leontief: (GFT-CEMRTS Class)

$$(25)\quad \ln(S_i/S_k) = \ln(\beta_i/\beta_k) + w^k_{ii}\ln(p_i) + w^k_{ik}\ln(p_k) + \Sigma_q w^k_{iq}\ln(z_q) + \xi^k_i$$

with restrictions (i) $w^k_{ik} + w^k_{ii} = 0$, and (ii) $w^k_{ii} = 1$.

Relaxed CES: (GFT-CEMRTS Class)

$$(26)\quad \ln(S_i/S_k) = \ln(\beta_i/\beta_k) + w^k_{ii}\ln(p_i) + w^k_{ik}\ln(p_k) + \Sigma_q w^k_{iq}\ln(z_q) + \xi^k_i$$

with restrictions (i) $w^k_{ik} = w^k_{jk}$, $i, j = 1, \ldots, n, \neq k$.

CES: (GFT-CEMRTS Class)

$$(27)\quad \ln(S_i/S_k) = \ln(\beta_i/\beta_k) + w^k_{ii}\ln(p_i) + w^k_{ik}\ln(p_k) + \Sigma_q w^k_{iq}\ln(z_q) + \xi^k_i$$

with restrictions (i) $w^k_{ii} + w^k_{ik} = 0$.

Leser-Houthakker: (GFT-CEMRTS Class) (see Leser, Houthakker)

$$(28)\quad \ln(S_i/S_k) = \ln(\beta_i/\beta_k) + w^k_{io}\ln(C) + w^k_{ii}\ln(p_i) + w^k_{ik}\ln(p_k) + \Sigma_q w^k_{iq}\ln(z_q) + \xi^k_i$$

with restrictions (i) $w^k_{ik} = w^k_{jk}$ $i, j = 1, \ldots, n, \neq k$, ($ii$) $w^k_{io} + w^k_{ii} + w^k_{ik} = 0$, ($iii$) $w^k_{ii} < 1$, $w^k_{ik} > -1$.

Relaxed CRES: (GFT-CRES Class) (see Mukerji)

$$(29)\quad \ln(S_i/S_k) = \ln(\beta_i/\beta_k) + b^k_{ii}\ln(x_i) + b^k_{ik}\ln(x_k) + \Sigma_q b^k_{iq}\ln(z_q) + \xi^k_i.$$

Strict CRES: (GFT-CRES Class)

$$(30)\quad \ln(S_i/S_k) = \ln(\beta_i/\beta_k) + b^k_{ii}\ln(x_i) + b^k_{ik}\ln(x_k) + \Sigma_q b^k_{iq}\ln(z_q) + \xi^k_i$$

with restrictions (i) $b^k_{ik} = b^k_{jk}$ $i, j = 1, \ldots, n, \neq k$. The null hypotheses and degrees of freedom associated with these functional forms are presented in table 3.[11]

[11] The concept of a functional form having an image within a GFT class implies an observational equivalence between demand behavior modeled by the GFT form and its neoclassical counterpart which does not allow for the possibility of changes in the production technology map because of changes in exogenous economic variables. This is easily demonstrated by comparing the ratio of expenditure shares derived under a GFT-CEMRTS form with CES restrictions [see (27)] and its neoclassical counterpart defined by $F(X; \beta, \partial, \nu) = (\Sigma_i \beta_i x_i^{-\partial})^{-\nu/\partial}$. Because the GFT-class functions implied by equations (24) through (30) are images of their neoclassical counterparts, all properties which are maintained in the neoclassical specification with respect to homogeneity, separability, and elasticity of substitution are maintained in the observationally equivalent GFT specification.

Results of the likelihood ratio tests for restricted functional forms with images in the GFT-CEMRTS class are presented in table 4. The tests indicated no favorable support for any of these functional form specifications relative to the unrestricted GFT-CEMRTS model.[12] Results of the likelihood ratio tests for restricted functional forms with images in the GFT-CRES class are presented in table 5. These tests showed that CRES forms with neoclassical restrictions on the set of technology changers also have little likelihood support in the empirical data.

Likelihood ratio tests indicated that GFT-class forms perform well relative to these seven strict classical functional forms. This finding provides impetus for further investigation of GFT-class forms to assess the support for maintaining the strict classical criterion in analyzing aggregate production systems.

[12] The Cobb-Douglas form, equation (24), was not tested separately. It is a nested hypothesis of the CES form which was strongly rejected.

Technical Change Biases

Following the convention of Lau, Antle and Capalbo, and others, we define direct Hicks-neutral technical change as expansion-path-preserving technical change. As such, a primal measure of Hicksian bias in technical change would assess the sensitivity of marginal rates of technical substitution at a given point in input space to changes in technology changing instruments. Estimated parameters in (13) for the GFT-CEMRTS system and (21) for the GFT-CRES system are the elasticities of the marginal rates of technical substitution with respect to exogenous variables. Thus, they are measures of Hicksian bias. Following Antle (1988, p. 357) and Antle and Capalbo (pp. 38–39), primal cost-share-weighted summary measures of Hicksian bias for input i with respect to technology changer h were computed at given input levels as

$$(31)\quad B_{i,h}(X, \gamma_h) = \Sigma_j S_j\, \partial \ln(f_i/f_j)/\partial \ln \gamma_h,$$

where S_i is the ith input's cost share, f_i is $\partial \ln F/$

Table 6. Average Share-Weighted Summary Measures of Hicksian Bias, GFT-CEMRTS System

Exogenous Variable	Input: Hired Labor	Machinery	Energy	Chemicals	Feed, Seed, & Livestock	Materials
$P_{Hired\ labor}$	1.037	−0.110	−0.596	0.177	−0.219	−0.028
	(.063)[a]	(.043)	(.075)	(.048)	(.033)	(.054)
$P_{Machinery}$	1.315	0.535	−0.308	−0.125	−0.264	−0.536
	(.190)	(.129)	(.225)	(.145)	(.100)	(.164)
P_{Energy}	0.445	−0.017	−2.332	−0.559	−0.002	0.393
	(.189)	(.128)	(.224)	(.144)	(.100)	(.164)
$P_{Chemicals}$	0.639	−0.173	0.064	0.765	−0.284	0.045
	(.085)	(.058)	(.101)	(.065)	(.045)	(.074)
$P_{F.S.L}$	0.782	−0.613	−3.071	−0.226	0.628	−0.543
	(.121)	(.082)	(.143)	(.092)	(.064)	(.105)
$P_{Materials}$	−1.732	−0.152	2.802	0.864	0.235	−0.180
	(.298)	(.202)	(.354)	(.228)	(.158)	(.258)
Real estate	1.363	−0.551	−0.310	0.052	−0.388	0.438
	(.289)	(.196)	(.343)	(.221)	(.153)	(.250)
Family labor	0.559	0.150	−0.455	0.131	−0.061	−0.270
	(.087)	(.059)	(.104)	(.067)	(.046)	(.075)
$\sigma_{Temperature}$	−0.028	0.301	0.587	−0.080	−0.225	0.141
	(.137)	(.093)	(.163)	(.105)	(.072)	(.119)
$Mean_{Temperature}$	−0.358	−0.011	−1.034	−0.780	0.125	0.429
	(.279)	(.189)	(.331)	(.213)	(.148)	(.242)
$\sigma_{Precipitation}$	0.013	0.003	−0.050	0.016	−0.014	0.022
	(.022)	(.015)	(.026)	(.017)	(.012)	(.019)
$Mean_{Precipitation}$	−0.065	0.082	−0.226	−0.097	−0.059	0.164
	(.052)	(.035)	(.062)	(.040)	(.028)	(.045)
Time	−0.021	−0.003	−0.086	0.065	−0.010	0.028
	(.022)	(.015)	(.026)	(.016)	(.011)	(.019)
Total cost	−1.857	0.636	3.801	−0.609	−0.191	0.436
	(.177)	(.120)	(.210)	(.135)	(.093)	(.153)

[a] Numbers in parentheses are the standard errors of the summary measures of Hicksian bias.

$\partial \ln x_i = \theta_i$, and γ_h is the hth exogenous variable. For the GFT-CEMRTS system,

$$B_{i,h}(X, \gamma_h) = \Sigma_j S_j w^j_{ih} = \Sigma_j S_j (w^k_{ih} - w^k_{jh}),$$

where k is the *numèraire* factor. For the GFT-CRES,

$$B_{i,h}(X, \gamma_h) = \Sigma_j S_j (b^k_{ih} - b^k_{jh}).$$

Equation (31) is qualitatively identical to Antle's (1988) and Antle and Capalbo's primal summary measures of Hicksian bias. For example, when technology changer γ_h is the trend variable, technical change is Hicks neutral, using, or saving with respect to time as $B_{i,h} = 0$, $B_{i,h} > 0$, or $B_{i,h} < 0$, respectively. The ith factor's relative marginal product is on average directly (inversely) related to variation in technology changer γ_h as $B_{i,h} > 0$ ($B_{i,h} < 0$). The summary measures of bias are reported at the data means in table 6 for the GFT-CEMRTS system estimates and in table 7 for the GFT-CRES system estimates.[13]

For the GFT-CEMRTS system, factor prices, budget, family labor, and mean precipitation generally have a significant (5% level) impact on relative marginal products. The two significant trend parameters suggest energy-saving and chemicals-using technical change over time.

In interpreting summary measures of Hicksian bias for the GFT-CRES system, it is useful to note that economic variables influence the technology map through the functions $x^*_j(C, P, Z)$, which are unknown. As a result, the influence of economic variables on technology choice is observed through factor utilization in equilibrium where $x_j = x^*_j(C, P, Z)$. We are unable to distinguish between price and budget effects for the GFT-CRES system as is possible for the GFT-CEMRTS system, but we can observe the combined influence of price and budget effects on the equilibrium factor usage choices. For the GFT-CRES system, hired labor, energy, chemicals, standard deviation of

[13] For the GFT-CEMRTS system, the parameter $w^j_{kk} = w_{kk} - w_{kk}$ takes on a value of zero, but its variance is not necessarily zero. Since the variance of w^j_{kk} is intractable, it is assumed to be zero when calculating the variance of the summary measures of Hicksian bias. As a result, the standard errors for summary measures of Hicksian bias represent lower bounds. The same is true for the GFT-CRES system summary measures of Hicksian bias.

Table 7. Average Share-Weighted Summary Measures of Hicksian Bias, GFT-CRES System

	Input					
Exogenous Variable	Hired Labor	Machinery	Energy	Chemicals	Feed, Seed, & Livestock	Materials
$x_{Hired\ Labor}$	0.428	−0.318	−0.265	0.108	0.191	−0.360
	(.137)[a]	(.109)	(.132)	(.108)	(.075)	(.095)
$x_{Machinery}$	−0.382	0.837	0.391	−0.531	−0.160	0.002
	(.288)	(.229)	(.277)	(.226)	(.158)	(.199)
x_{Energy}	−0.250	0.002	0.803	0.211	−0.039	−0.008
	(.106)	(.084)	(.102)	(.083)	(.058)	(.073)
$x_{Chemicals}$	0.816	−0.433	−0.544	−0.150	0.284	−0.530
	(.282)	(.224)	(.271)	(.221)	(.154)	(.195)
$x_{F.S.L.}$	−1.224	0.210	0.912	−0.396	0.236	0.041
	(.335)	(.266)	(.323)	(.263)	(.183)	(.232)
$x_{Materials}$	0.472	−0.405	−0.427	−0.098	−0.137	0.418
	(.246)	(.195)	(.236)	(.193)	(.134)	(.170)
Real estate	−0.568	0.110	1.150	−0.419	−0.364	0.871
	(.496)	(.394)	(.477)	(.389)	(.272)	(.343)
Family labor	−0.052	0.116	−0.067	0.322	−0.094	0.026
	(.159)	(.127)	(.153)	(.125)	(.087)	(.110)
$\sigma_{Temperature}$	0.252	0.520	0.361	−0.513	−0.261	0.078
	(.206)	(.164)	(.198)	(.162)	(.113)	(.142)
$Mean_{Temperature}$	0.520	−0.648	−1.034	−0.050	0.457	−0.478
	(.451)	(.358)	(.434)	(.354)	(.247)	(.312)
$\sigma_{Precipitation}$	−0.030	0.004	0.016	0.048	−0.019	0.031
	(.039)	(.031)	(.038)	(.031)	(.021)	(.027)
$Mean_{Precipitation}$	−0.012	−0.025	−0.128	−0.066	0.047	−0.019
	(.096)	(.076)	(.093)	(.075)	(.053)	(.067)
Time	0.019	0.164	0.193	0.115	−0.175	0.128
	(.042)	(.033)	(.040)	(.033)	(.023)	(.029)

[a] Numbers in parentheses are the standard errors of the summary measures of Hicksian bias.

temperature, and trend often have a significant impact on relative marginal products. Significant parameters for the trend variable suggest factor-using technical change over time for machinery, energy, chemicals, and materials and factor-saving technical change for the feed, seed, and livestock input category.

For elements of γ which are common to the two functional specifications, the only significant Hicksian summary measure that differs in sign is on the trend variable for energy. The GFT-CEMRTS model suggests that Hicks technical change is on average significantly energy saving, and the GFT-CRES model suggests that Hicks technical change is on average significantly energy using over time.

In interpreting the Hicksian summary measures, the suggestion that these measures are indicative of induced technical change has been avoided. The induced technical change hypothesis implies a causal temporal relationship. We have not included expectations of technical change, either through dynamic modeling (e.g., Antle 1988) or through factor augmentation instruments (Kawagoe, Otsuka, and Hayami) in this study. As a result technical change cannot be interpreted as induced. However, the GFT modeling framework does not limit one a priori to Hicksian-bias technical analysis; for example, factor augmentation instruments and lagged economic variables could be included in the vector of technical changer variables, γ, to investigate induced bias.

Estimated Elasticities

Factor demand elasticities were evaluated at GFT-CEMRTS parameter estimate values associated with the AR(2) hypothesis which generated the largest likelihood support over the stability region. The mean value and standard deviation of computed Marshallian uncompensated factor demand elasticities are reported in table 8.

With the exception of the hired labor factor, all own-price elasticities were negative, and all

Table 8. Mean and Standard Deviation of Marshallian Uncompensated Factor Demand Elasticities, GFT-CEMRTS System, $\Phi_1 = -0.40$, $\Phi_2 = 0.90$

	Equation					
Exogenous Variable	Hired Labor	Machinery	Energy	Chemicals	Feed, Seed, & Livestock	Materials
$P_{Hired\ Labor}$	0.037	−0.110	−0.596	0.177	−0.219	−0.028
	(.022)[a]	(.022)	(.022)	(.022)	(.022)	(.022)
$P_{Machinery}$	1.315	−0.465	−0.308	−0.125	−0.264	−0.536
	(.026)	(.026)	(.026)	(.026)	(.026)	(.026)
P_{Energy}	0.445	−0.017	−3.332	−0.559	−0.002	0.393
	(.063)	(.063)	(.063)	(.063)	(.063)	(.063)
$P_{Chemicals}$	0.639	−0.173	0.064	−0.235	−0.284	0.045
	(.015)	(.015)	(.015)	(.015)	(.015)	(.015)
$P_{F.S.L}$	0.782	−0.613	−3.071	−0.226	−0.372	−0.543
	(.082)	(.082)	(.082)	(.082)	(.082)	(.082)
$P_{Materials}$	−1.732	−0.152	2.802	0.864	0.235	−1.180
	(.073)	(.073)	(.073)	(.073)	(.073)	(.073)
Real estate	1.363	−0.551	−0.310	0.052	−0.388	0.438
	(.045)	(.045)	(.045)	(.045)	(.045)	(.045)
Family labor	0.559	0.150	−0.455	0.131	−0.061	−0.270
	(.008)	(.008)	(.008)	(.008)	(.008)	(.008)
$\sigma_{Temperature}$	−0.028	0.301	0.587	−0.080	−0.225	0.141
	(.022)	(.022)	(.022)	(.022)	(.022)	(.022)
$Mean_{Temperature}$	−0.358	−0.011	−1.034	−0.780	0.125	0.429
	(.037)	(.037)	(.037)	(.037)	(.037)	(.037)
$\sigma_{Precipitation}$	0.013	0.003	−0.050	0.016	−0.014	0.022
	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)
$Mean_{Precipitation}$	−0.065	0.082	−0.226	−0.097	−0.058	0.164
	(.008)	(.008)	(.008)	(.008)	(.008)	(.008)
Time	−0.021	−0.003	−0.086	0.065	−0.010	0.028
	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)
Total cost	−0.857	1.636	4.801	0.391	0.809	1.436
	(.092)	(.092)	(.092)	(.092)	(.092)	(.092)

[a] Numbers in parentheses are the standard deviations of the distributions of elasticity values.

elasticities with respect to the expenditure constraint C were positive. The mean own-price elasticity for hired labor is not significantly different from zero. This finding is consistent with recent work by Shumway and Alexander for this region. The sluggish adjustment of hired labor toward its optimal level is also consistent with recent estimates by Baffes and Vasavada for the U.S. agricultural sector. Given the large decrease in hired labor usage over the sample period, its negative elasticity with respect to the expenditure constraint is perhaps not surprising.

Mean elasticities indicate that usage of energy, materials, and feed, seed, and livestock marketing services are substitutes for (i.e., inversely related to) family labor. In addition, usage of machinery, energy, and feed, seed, and livestock marketing services are substitutes for real estate. Other variable inputs are complements to family labor and real estate. Factor demand elasticities with respect to the real estate and family labor variables indicate that changes in these variables elicit important changes in the mix of the factor bundle. Elasticities with respect to weather variables suggest that factor demand is more sensitive to temperature than precipitation, and more sensitive to mean changes than deviations from the mean. Although hypothesis tests fail to reject the significance of a trend variable, factor demands are relatively unresponsive to year.

Of thirty cross-price relationships among variable inputs, nineteen are complements and eleven are substitutes. Because the price elasticities of demand are the expenditure-constant profit maximization (Marshallian uncompensated) variety rather than output-constant cost-minimization (Hicksian) or unconstrained profit-maximization (Marshallian) elasticities, the symmetry property of the cross-partial derivatives does not imply symmetry in signs of the cross-price elasticities. In fact, signs for five of the fifteen pairs of cross-price elasticities differ.

Compared to prior elasticity estimates for this region (Gempesaw and Dunn, Shumway and Alexander), the absolute magnitudes of these estimates tend to be higher for both own-price and cross-price relationships. Both prior sets of estimates were compensated Marshallian elasticities obtained under the assumptions of zero serial correlation, a strict neoclassical production technology, and technology change invariant to changes in economic variables. Although signs and magnitudes of specific elasticities differ from the prior estimates, there is strong evidence from all the studies of both complements and substitutes among pairs of inputs.

Unlike the previous studies, homogeneity of degree zero of the factor demand equations is not a maintained hypothesis in this model. Changes in budget constraint parameters do influence the shape of the technology map giving sums of elasticities (at the means) with respect to input prices and cost ranging from $-.413$ for materials to .629 for hired labor. For only two inputs (feed, seed, and livestock marketing services and machinery), do proportionate changes in input prices and the cost constraint have little impact on the quantity of the input demanded.

Conclusions

This research has focused on empirical characterization of technological relationships among factors in aggregate agricultural production processes. The generalized Fechner-Thurstone functional specification was employed to relax strict neoclassical efficiency constraints and to provide a means for modeling systematic and stochastic technical change without exclusive reliance on time trend variables.

Two GFT-class models were specified under a second-order autoregressive schema: The constant elasticity of marginal rate of technical substitution model (GFT-CEMRTS), and the constant ratio of elasticity of substitution model (GFT-CRES). Each GFT-class model was tested against commonly maintained technical change hypotheses as well as classical functional forms having technology images nested within their class. Likelihood ratio tests indicated strong support for rejection of both the simplified technical change specifications and the classical functional forms relative to their unrestricted GFT-class counterparts.

Summary measures of Hicksian bias suggested that changes in economic variables exhibit a significant systematic effect on the shape of regional agricultural production technology. Both models found that temporal technical change was significantly chemicals using, but they rendered conflicting conclusions about the bias for energy. The GFT-CRES model also suggested that temporal technical change was significantly factor using for machinery and materials and factor saving for the feed, seed, and livestock input category.

All GFT-CEMRTS own-price Marshallian uncompensated factor demand elasticities were negative or not significantly positive. Five of the six demand elasticities with respect to cost were

positive. Because changes in the budget constraint parameters influenced the shape of the technology map, input demand equations were not homogenous of degree zero. Elasticities suggest a proportionate increase in all variable input prices and the cost constraint would substantially increase the demand for hired labor, energy, and chemicals and decrease the demand for materials.

Approximately two-thirds of the pairs of variable input demand relationships were complementary. Half of the variable inputs were complements to each of the fixed inputs (real estate and family labor) and half were substitutes. Relatively large cross-price elasticities were evident for several of the inputs. The estimates clearly document the fundamental and powerful impact on input demands and particularly on input combinations of federal agricultural policy that has frequently sought to alter the quantity of land used in production.

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Input Allocation in Multicrop Systems

Richard E. Just, David Zilberman, Eithan Hochman, and Ziv Bar-Shira

Using data only on aggregate variable input use and land allocation, this paper suggests a methodology for allocating variable input use among crops and improvement of regional crop budget information. Two approaches for estimation of variable input allocations among production activities are examined. One relies on behavioral rules whereby input allocations follow accepted rules of thumb. The alternative approach is derived from profit maximization where input use responds instantaneously to changes in input and output prices. The behavioral rules dominate instantaneous response to prices in explaining the data analyzed in this paper and suggest the validity of a simple behavioral approach for developing enterprise budgets and cost of production estimates.

Key words: behavioral rules, enterprise budgets, profit maximization, variable input allocation.

A major responsibility of farm management economists is to develop reliable crop budgets. Too often crop budgets are developed by guesstimates based on only a handful of informal interviews rather than formal statistical analysis.[1] Also, since 1973 the U.S. Secretary of Agriculture has been legislatively mandated to conduct national cost of production studies for selected crops. Because most farms produce several crops and do not record input use by crop, producing reliable crop budgets and enterprise cost of production estimates requires sound estimation of variable input allocations among crops (Hornbaker, Dixon, and Sonka).

One approach is to survey farmers, asking them to estimate the amounts of each input they allocate to each crop. Because of survey cost considerations, this approach has been feasible only infrequently.[2] Another approach is to use data on total farm inputs by category to develop systematic estimates of use per acre by crop. Formal methodologies for estimating variable input allocations have not been developed until recently (Shumway, Pope, and Nash; Just, Zilberman, and Hochman). Cost of survey considerations have lead Baum et al. to propose the use of systematic procedures for allocating total farm input use among crops as a means of improving the quality of cost of production estimates.

One purpose of this paper is to suggest a simple procedure for estimating these allocations. The procedure considers a typical pattern of farm-level data availability (e.g., as with many computerized farm record-keeping systems). The estimated relationship describes farmer behavior in the traditional paradigm under which crop budgets are strictly appropriate (e.g., linear programming as it was applied historically). Specifically, farmers are supposed to behave as if their production functions follow constant returns to scale with fixed input/land ratios. These ratios are assumed to be based on regional av-

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[1] A typical statement of methodology in an extension farm management budget publication is, "The following data are composite figures gathered from a representative group of . . . growers." (This statement appears in a California county extension publication but appears sufficiently typical that no one such publication should be singled out.)

[2] For example, the USDA Cost and Returns Survey attempts only to identify input use by crop for one crop each year with the chosen crop changing from year to year. By comparison, data on total farm inputs by input category is collected every year along with acreage and production by crop.

erages with modifications for seasonal and farm-specific conditions. Necessary data include only records on land allocation by crop (or an alternative measure of activity level for livestock), total purchases by input, and total sales by output.

Typical criticisms of crop budgets are their implicit assumption of fixed proportions production and lack of information on appropriate input-use response to changes in prices. A second purpose of this paper is to provide a test for the validity of this fixed proportions assumption in reflecting farmer behavior. Two approaches for estimation of variable input allocations among activities are examined. One relies on behavioral rules whereby input allocations (input/land ratios) follow accepted practices. The alternative approach is derived from the traditional profit maximization paradigm, where input use responds instantaneously to changes in input and output prices. The former dominates the latter statistically in the empirical case of this paper and suggests the validity of a simple behavioral approach for developing enterprise budgets and cost-of-production estimates.

Allocation of Inputs Among Crops: A Behavioral Approach

The behavioral approach of this paper describes variable input allocation in a region with a group of I farmers ($i = 1, 2, \ldots, I$) producing K crops ($k = 1, 2, \ldots, K$) using J inputs ($j = 1, 2, \ldots, J$) over a period of T years ($t = 1, 2, \ldots, T$).[3] The statistical analysis consists of estimating the allocation of variable inputs among crops. The two items of information used for these estimations are L_{kit}, which is the area allocated by individual i to the production of crop k at time t; and X_{jit}, which is the aggregate quantity of input j used by individual i at time t. Obviously,

$$(1) \qquad X_{jit} = \sum_{k=1}^{K} X_{kjit},$$

where X_{kjit} is the unobserved quantity of input j allocated by individual i at time t to production of crop k.

Information on X_{jit} is likely to exist for many farms because most bookkeeping and accounting systems register transactions between the farmer and other agents. However, internal transactions that allocate inputs among activities are rarely recorded. Land allocation data are more likely to exist than data on allocation of variable inputs. Land allocation is easily measured and is the main element of farmers' production plans (Hornbaker, Dixon, and Sonka).

The estimated relationships of the allocation of variable inputs among crops are derived from assumptions about the rules which characterize farmer behavior. Farmers are assumed to act as though their production functions have constant returns to scale. Hence, their decisions consist of the variable input/land ratios and land allocations. Following Rogers, Schultz, and others, farmers are assumed to exchange information in assessing technologies and markets and to imitate one another. They also receive essentially the same information from extension sources and the media. While imitation and similar information lead to uniformity in behavior, differences in farm and farmer characteristics lead to systematic variations among individuals. This permits input/land ratio decisions to be characterized by an overall average level, an annual deviation reflecting economic and weather variations and a systematic farmer deviation reflecting land quality, human ability, and perceptions.[4]

Let $x_{kjit} = X_{kjit}/L_{kit}$ be the quantity of input j per unit of land used at time t by farmer i in producing crop k. Then the systematic element of x_{kjit} denoted by x^*_{kjit} can be decomposed following

$$(2) \qquad x^*_{kjit} = \alpha_{kj} + \beta_{ji} + \gamma_{jt},$$

where α_{kj} is an average regional use of variable input j per unit of land in the production of crop k throughout the period of analysis, γ_{jt} denotes deviations from the regional average for use of input j at time t, and β_{ji} denotes deviations by farmer i from the regional average for use of input j. Using (1) and (2), the components of x^*_{kjit} can be estimated following

$$(3) \qquad X_{jit} = \sum_{k=1}^{K} [\alpha_{kj} + \beta_{ji} + \gamma_{jt}]\, L_{kit} + \epsilon_{jit},$$

where ϵ_{jit} is a random deviation associated with farmer i and input j at time t. For empirical pur-

[3] Here we assume that a crop uses a uniform technology on all land allocated to that crop. If more than one technology is used in producing a crop (e.g., irrigation and nonirrigation), then the methodology carries through if crops are defined by crop-technology combinations.

[4] Baum et al.'s suggestion for variable input allocation is a special case of this approach with no farmer or time differences (their sample had only one time period).

poses, ϵ_{jit} is assumed to be normally and independently distributed.[5]

Estimation of equation (3) requires regressing total use of each variable input on the acreages allocated to each of the crops crossed with dummy variables. The dummy variables correspond to the crop effect, farmer effect, and time effect. The sum of the estimated parameters $\hat{\alpha}_{kj} + \hat{\beta}_{ji} + \hat{\gamma}_{jt}$, is an estimate of the per acre allocation of variable input j to crop k by farmer i at time t. Multiplication of this estimate by the land allocated to the crop results in the behavioral estimate of the allocation of variable input j to crop k at time t,

$$(4) \qquad \hat{X}^b_{kjit} = [\hat{\alpha}_{kj} + \hat{\beta}_{ji} + \hat{\gamma}_{jt}]\, L_{kit},$$

where the superscript b denotes the behavioral model.

A Profit Maximization Approach to Allocation of Inputs

This section outlines a profit maximization approach which parallels the structure and data requirements of the behavioral approach. To obtain an estimable relationship describing variable input allocation, note that the short-run profit maximization problem of the firm is

$$(5) \qquad \max_{X_{kjit}} \sum_{k=1}^{K} P_{kt}\, Q_{kit} - \sum_{j=1}^{J} W_{jt}\, X_{jit},$$

$$\text{s.t. } Q_{kit} = f_{kit}(X_{k1it}, X_{k2it}, X_{k2it}, \ldots, X_{kJit}, L_{kit}), \quad k = 1, 2, \ldots, K,$$

$$X_{jit} = \sum_{k=1}^{K} X_{kjit}$$

where P_{kt} is the price of output k at time t, W_{jt} is the price of input j at time t, and f_{kit} is the production function of farmer i for output k at time t. The first-order conditions determining variable input use for (5) are

$$W_{jt} = P_{kt} \frac{\partial f_{kit}}{\partial X_{kjit}}, \; k = 1, \ldots, K; j = 1, \ldots, J.$$

Using elasticities, these conditions become

$$(6) \qquad X_{kjit} = \frac{R_{kit}}{W_{jt}} e_{kjit},$$

where $e_{kjit} = (\partial f_{kit}/\partial X_{kjit})\,(X_{kjit}/Q_{kit})$ is the elasticity of input j in production of output k by farmer i at time t and R_{kit} is revenue from sales of good k by farmer i at time t.

The e_{kjit} are elasticities at the optimal solution. They are not assumed to be constant and hence their use does not imply Cobb-Douglas production. Suppose they vary among farmers, among crops, and over time and can be decomposed following

$$(7) \qquad e_{kjit} = a_{kj} + b_{ji} + c_{jt},$$

where a_{kj} is the crop effect, b_{ji} is the farm effect and c_{jt} is the time (technological) effect. Introducing (7) into (6) and aggregating over crops yields the estimable form

$$(8) \qquad X_{jit} = \sum_{k=1}^{K} (a_{kj} + b_{ji} + c_{jt}]\frac{R_{kit}}{W_{jt}} + \zeta_{jit}, j = 1, \ldots, J; \quad i = 1, \ldots, I; \quad t = 1, \ldots, T;$$

where ζ_{jit} is a random deviation associated with farmer i, input j, and time t. For empirical purposes, ζ_{jit} is assumed normally and independently distributed.[6]

The estimated parameters of equation (8) can be used to translate revenue data into profit maximization estimates of variable input allocations among crops following

[5] The work of Hornbaker, Dixon, and Sonka suggests a heteroscedastic specification for the disturbance in general, but it does not appear necessary in the sample of this paper.

[6] A recent paper by Hornbaker, Dixon, and Sonka uses an alternative cost function approach which in the notation of this paper follows:

$$W_{jt} X_{jit} = \sum_{k=1}^{K} c_{kjit} L_{kit},$$

where c_{kjit} are ad hoc functions of acreages, yield, and hired labor. Although this function is represented as following from Just, Zilberman, and Hochman, it is clear from (8) that this equation cannot follow under profit maximization unless c_{kjit} involves the price of crop k. One must thus conclude that their empirical work is in the spirit of the behavioral model in (3) rather than a profit maximization model such as Just, Zilberman, and Hochman's. Indeed, if $c_{kjit} = \alpha_{kj} + \beta_{ji} + \gamma_{jt}$ and input prices are constant within the sample (as they argue for their partitioned samples), then the two models are identical. An assumption of cost minimization alone is not sufficient for specification of multi-output cost equations because both outputs and input-output ratios respond to output prices in general.

$$(9)\qquad \hat{X}^{p}_{kjit} = (\hat{a}_{kj} + \hat{b}_{jt} + \hat{c}_{ji})\frac{R_{kit}}{W_{jt}},$$

where $\hat{a}_{kj}$, $\hat{b}_{ji}$, and $\hat{c}_{jt}$ are the estimates of parameters in (8) and the superscript p denotes the profit maximization model. Comparison of equations (4) through (9) reveals the difference between the behavioral and profit maximization models. Both models require data on total variable input use. While the behavioral model requires data on land allocation among crops, the profit maximization model requires data on revenue distribution among crops and variable input prices (or simply total variable input expenditures if both sides of the estimating equation are multiplied by input price). Crop, time, and farmer effects are multiplied by the land allocation in the behavioral model, while they are multiplied by the ratio of revenue to input price in the profit maximization model.

An Application to the Estimation of Input Allocations

An illustrative application of the framework is provided by an empirical analysis of farm production data from two villages, Hazeva and Ein-Yahav, in the Arava region of Israel. This desert region is similar in production practices and technology to the Coachella Valley of California. It specializes in production of off-season vegetables. The villages consist of 85 to 101 farm units per village, respectively. Interviews with farmers revealed that individual farmers are independent producers and decision makers, but inputs are purchased and outputs are sold through cooperatives.

While the farms are small in land area compared to most U.S. farms, agricultural practices are intensive, with revenues in the neighborhood of $80,000 per farm. Most farms use computerized accounting systems similar to those available in the United States. Farmers rely on extension agents and communication with other farmers to learn about appropriate production practices, and they adapt available information to their individual situations. This suggests a framework with similar perceptions, but individualistic adaptations. The independent nature of individual farmers is reflected by a wide variation in the share of land allocated to different crops among farms.

Through a series of nontechnical questions, it was apparent that farmers behave as if their production functions follow constant returns to scale. Consistent with these perceptions, recommended input-output ratios (norms) are developed and distributed by the farm advisers. These norms are regarded much like U.S. crop budgets; it is not clear to what extent the norms are designed to guide optimal behavior as opposed to summarizing average regional behavior. Individual farmers take the norms into consideration but deviate according to their specific personal and locational characteristics.

Data on total water use and purchased input expenditure as well as on revenues by crop were obtained from the village's accounting offices. Available data are for the years 1973–82 for Ein-Yahav and 1977–82 for Hazeva. All monetary data were converted to real terms. Land allocations were available from crop insurance records. The number of inputs that can be analyzed by this methodology is determined by the number of input categories that are tallied separately and consistently in the sample population. Unfortunately, for the sample used here data on only two inputs were available. This breakdown is the most important for farming in this region because water is the most scarce local input and is the major constraint on growth of the region; knowledge of water use patterns is needed for policy and planning purposes. All other inputs are purchased externally and are of primary interest both to farmers and those granting credit as they affect overall credit needs. Although the data only divide inputs into two categories, this application serves to illustrate the methodology which easily generalizes to many inputs.

Behavioristic Estimates

The ordinary least squares estimates of parameters of equation (4) for two inputs—water and "other" inputs (as measured by expenditures)—and five outputs—bell peppers, tomatoes, onions, melons, and eggplant—are presented in table 1. Table 1 contains the estimates of the α_{kj}'s. and γ_{jt}'s. The numerous estimates of the β_{ji}'s are not reported to save space but are reflected in graphical results discussed below. In order to prevent singularity of the explanatory variable matrix, the results are normalized on the fiftieth farm and the year 1980 in each case. That is, $\beta_{50,j} = \gamma_{j,1980} = 0$, so the α_{kj}'s measure the per dunam inputs of the fiftieth farm in 1980 (a dunam is 1,000 square meters).

The water input is measured in cubic meters per dunam. Thus, for example, the coefficient for bell peppers in Hazeva implies that the av-

Table 1. Behavioral Allocation Estimates

	Hazeva		Ein-Yahav	
Crop	Water	Other	Water	Other
Bell peppers	1,411	17,096	1,005	11,911
	(12.24)	(7.00)	(12.04)	(9.67)
Tomatoes	752	14,814	874	12,830
	(3.89)	(3.61)	(5.30)	(5.27)
Onions	1,009	17,242	961	13,923
	(8.10)	(6.53)	(7.39)	(7.26)
Melons	414	7,121	393	1,170
	(4.20)	(3.41)	(3.96)	(0.79)
Eggplant	1,299	20.963	649	6,415
	(6.00)	(4.57)	(3.54)	(2.38)
1973	NA	NA	412	−4,710
			(5.13)	(−3.97)
1974	NA	NA	−32	−5,456
			(−0.49)	(−5.59)
1975	NA	NA	111	−3,779
			(1.84)	(−4.24)
1976	NA	NA	190	−141
			(3.97)	(−0.20)
1977	−184	3,044	192	860
	(−3.59)	(2.79)	(5.12)	(1.55)
1978	−2	1,100	211	5,186
	(−0.03)	(1.03)	(5.35)	(8.91)
1979	31	6,081	41	11,342
	(0.68)	(6.27)	(1.13)	(21.28)
1980	0	0	0	0
1981	−63	−4,693	162	−1,820
	(−1.72)	(−6.07)	(4.40)	(−3.34)
1982	84	7,661	91	3,870
	(1.76)	(7.58)	(2.37)	(6.86)
R^2	.971	.955	.965	.961

Note: Water input is in cubic meters; other expenditures are in 1980 shekels. Numbers in parentheses are t-ratios.

erage water application on farm 50 in 1980 is 1,411 milimeters. This water application rate converts to acre feet per acre by dividing by 304.8. Thus, the water application rate on farm 50 in 1980 is 4.63 acre feet per acre. Similarly, the coefficient for 1977 in the Hazeva water equation implies that water use averaged 184 milimeters (.60 acre feet per acre) less than 1980. These annual variations represent a response to both prices and temperature. Other inputs are measured in 1980 shekels, so the coefficients of individual crops measure average real expenditure for farm 50 in 1980 with year coefficients measuring annual deviations from 1980. A test of the hypotheses of no difference in input use per dunam among farmers ($\beta_{ij} = 0$ for all i and j) was rejected at the 1% level.

Table 1 shows that all of the crop coefficients (α_{kj}'s) are different from zero at high significance levels. Furthermore, the crop coefficients dominate the time coefficients (γ_{jt}'s). In 1980 (the base year), the average consumption of water by most crops in Hazeva was higher than in Ein-Yahav, even though water prices were not substantially different. Upon noting that the time coefficients of Ein-Yahav are larger than Hazeva, however, it is not clear that the estimates for 1980 alone give a clear picture of input use over the entire sample period.

For this purpose, table 2 presents the average estimated input use over the last six years of the sample (see the lines labeled "behavioral"). Observations are available from both settlements for these years. The sample average water use coefficients indicate that water use per dunam by crop differs little between the two settlements except in bell peppers and eggplant, even though the difference among crops is quite large. Consistent with farmer interviews, melons use considerably less inputs than all other crops. The sharp difference in water use levels on bell peppers is consistent with observed cropping patterns. Ein-Yahav is much more specialized in bell pepper production than Hazeva. One plausible explanation is that the lower water coefficient for Ein-Yahav reflects a comparative ad-

Table 2. Estimated and Recommended Input Use

	Peppers	Tomatoes	Onions	Melons	Eggplant
Hzaeva water					
Behavioral	1,491	856	1,053	518	1,382
Profit max	1,432	1,544	870	405	923
Norms	1,100–1,300	800–1,100	900–1,100	450–600	800–1,100
Ein-Yahav water					
Behavioral	1,174	1,053	1,152	572	851
Profit max	1,270	660	812	503	421
Norms	1,100–1,300	800–1,100	900–1,100	450–600	800–1,100
Hazeva other					
Behavioral	20,063	17,940	19,569	9,659	23,534
Profit max	19,622	31,885	16,535	6,807	15,675
Ein-Yahav other					
Behavioral	17,330	18,098	18,635	5,788	11,416
Profit max	18,423	9.688	11,829	7,662	6,623

Note: Water input is in cubic meters; other expenditures are in 1980 shekels.

vantage in bell pepper production.

An explanation suggested by interviews with farm advisers is that Ein-Yahav specializes in bell peppers because it is less labor intensive and Ein-Yahav strongly adheres to the principle of self-reliant labor use for ideological reasons. If labor and water are complementary inputs, which seems plausible, then water use is lower when labor is limited. Unfortunately, no labor data are available to examine this possibility because most nonfamily labor is by unpaid volunteers who exchange services for room and board. The complementarity of water and harvest labor is particularly apparent in table 2 because water use is virtually the same in both settlements for onions and melons (crops harvested mechanically), while water use is lower in Ein-Yahav for bell peppers and eggplant (crops harvested manually).

Similar conclusions apply to other inputs as well. Small differences among crops exist between the settlements except for eggplant, while melons require only about half the other expenditures of other crops. Melons are generally a low-effort, low-revenue residual crop, while the other crops except for eggplant are considered as high-value cash crops. Eggplant is regarded as a high-value crop by Hazeva and a marginal crop by Ein-Yahav. The intensity of input uses differs accordingly.

Some of the time coefficients for water use require special explanation. In Ein-Yahav, water use in the first year was considerably more than in the rest of the period because the settlement was new and soils required initial leaching (around 300 cubic meters per dunam). The differences between other years mostly reflect climatic conditions. The lower levels of use after 1978 may reflect increasing use of drip irrigation technology and computer automation of irrigation applications.[7]

The time coefficients of other expenditures increase over time during the 1970s (Ein-Yahav). The coefficients of the late 1970s are substantially higher than the early 1970s. This rise likely reflects substantial movement toward the use of plastics and computers with drip irrigation systems. The decline after 1979 may be due to learning and a misreporting of fixed expenditures as variable expenses. Finally, according to local farm advisers, 1978 and 1979 required more expenditures on other inputs because of high energy prices and problems requiring exceptionally high pesticide use. The high level of expenditures in 1982 may be due to inefficiency connected with an exploding inflation process (to over 300% per year) which required a financial "learning by doing" adjustment.

Profit Maximization Estimates

Table 3 presents the estimates of equation (8) for water and expenditures on other inputs for the five crops and two settlements. These estimates correspond to the behavioral estimates in table 1. Again, only the crop and input coefficients are presented, while the more numerous farmer coefficients are not reported in tabular form. The farmer effects in most cases are not significantly different from zero individually,

[7] Note that as technologies were changed, farmers continued to use only one technology on each crop.

Table 3. Profit Maximization Allocation Estimates

	Hazeva		Ein-Yahav	
Crop	Water	Other	Water	Other
Bell peppers	.046	.189	.057	.187
	(8.25)	(5.73)	(8.24)	(4.92)
Tomatoes	.030	.216	.057	.191
	(4.26)	(5.37)	(6.63)	(3.70)
Onions	.038	.239	.059	.244
	(5.38)	(5.67)	(6.50)	(4.64)
Melons	.011	.070	.046	.174
	(2.29)	(2.29)	(5.33)	(3.54)
Eggplant	.031	.175	.054	.199
	(2.79)	(2.78)	(4.38)	(2.50)
1973	NA	NA	−.008	−.067
			(−2.20)	(−2.51)
1974	NA	NA	−.024	−.041
			(−7.40)	(−1.83)
1975	NA	NA	−.014	−.040
			(−5.21)	(−2.58)
1976	NA	NA	−.013	−.048
			(−6.47)	(−4.71)
1977	.004	.060	.017	.016
	(1.62)	(3.97)	(6.99)	(1.53)
1978	.014	.051	.012	.057
	(4.74)	(3.20)	(5.29)	(5.49)
1979	.005	.080	.003	.168
	(2.79)	(7.07)	(1.36)	(16.07)
1980	0	0	0	0
1981	.010	−.035	.005	−.001
	(5.18)	(−3.18)	(1.91)	(−.06)
1982	.032	.295	.044	.306
	(12.53)	(19.46)	(13.32)	(17.04)
R^2	.955	.942	.933	.933

Note: Water input is in cubic meters, other expenditures are in 1980 shekels. Numbers in parentheses are *t*-ratios.

while the time and crop effects are mostly significant.

The coefficients in table 3 are interpreted according to the specification of equation (8). The coefficient for each crop in the water equation measures average water elasticity implied by profit maximization for farm 50 in the year 1980. The time dummy coefficients measure deviations in this elasticity for other years from 1980. The coefficients of the equations for other inputs measure similar concepts for expenditures per dunam.

Statistical Comparison of Alternative Models

An obvious criterion to compare the models estimated in tables 1 and 3 is the R^2 statistic. Both models obtain high and nearly similar R^2 statistics. However, for both inputs and both settlements, the behavioral model fits the data better. In the case of Ein-Yahav, the behavioral model results in about half as much unexplained variation as the profit maximization model (as reflected by $1 - R^2$). While these differences in unexplained variation are small, the superior performance of the behavioral model in four out of four cases has a significance level of .06 according to the simple signs test (on the difference in R^2 statistics between models), implying rejection of the hypothesis of equal performance by the two models. (See Siegel for details on the signs test.)

To compare more formally the profit maximization and behavioral models, a nonnested hypothesis test (Davidson and MacKinnon) was performed by including the predicted values from each model as an additional explanatory variable in the other model (see table 4). While the test is statistically inconclusive except at very high significance levels, the behavioral predictors contribute substantially more to the profit maximization model than vice versa (observe the estimated coefficients in table 4). Also, the *t*-

Table 4. Statistics for Nonnested Hypothesis Tests of Behavioral and Profit Maximization Models

	Coefficient of Behavioral Predictions in Profit Max Model	Coefficient of Profit Max Predictions in Behavioral Model
Hazeva water	0.77	0.34
	(14.23)	(5.75)
Ein-Yahav water	0.85	0.22
	(24.30)	(5.69)
Hazeva other	0.76	0.34
	(10.12)	(4.28)
Ein-Yahav other	0.87	0.18
	(22.39)	(4.17)

Note: Numbers in parentheses are t-ratios.

statistics for the behavioral predictors in the profit maximization model are considerably more significant than are the profit maximization predictors in the behavioral model in every case. Thus, the behavioral model appears superior to the profit mazimization model.

Plausibility

In order to evaluate the quality of the estimators of the variable input parameters more carefully, a standard of comparison is useful. Water use recommendations by farm advisers in the region is one plausible basis for comparison. These recommendations are reported in the line labeled "Norms" in table 2. The norms represent a range of water application rates that the advisers consider to reflect sound agricultural practices in the region. The norms are based on adviser observations of actual farmers' behavior. Thus, they are likely to include the actual regional averages; regional averages substantially outside the range of values suggested by the norms are unreasonable.

To compare the profit maximization model to the behavioral model on the basis of norms, the predicted allocations implied by table 3 are averaged over time (1977 to 1982) and farmers, and reported in the lines labeled "Profit Max" of table 2.[8] The profit maximization estimates of input use vary somewhat more among crops than the behavioral estimates. Also, some of the predictions seem unreasonable compared to the regional norms. For example, the profit maximization estimate severely overshoots the tomato water norms for Hazeva and undershoots for Ein-Yahav, while the behavioral estimate is within the recommended interval in each case. For Hazeva, all of the estimated water requirements indicated by the profit maximization model, except eggplant, are outside the regional production norms. For Ein-Yahav, three of the five estimated water requirements are substantially outside regional norms, with the eggplant estimate about 48% below the minimum bound.

By comparison, only two of the behavioral estimates are outside the production norms in Hazeva and only one estimate is outside in Ein-Yahav. The Ein-Yahav case is onions, and even then the estimate is only 5% above the upper norm. Ein-Yahav may conform more closely to the norms because it is an older and larger settlement; because of more experience, farm advisers give greater weight to Ein-Yahav than Hazeva in formulating norms. Furthermore, the other cases where behavioral estimates exceed the norms conform reasonably to farm adviser perceptions of producer behavior. For example, farm advisers indicated that Hazeva farmers tend to overirrigate peppers. Also, the average use of water on eggplant on the two settlements combined is within the norms which are intended to apply as regional averages.

Turning to the other expenses, the major differences between the two sets of estimates is that the profit maximization estimates are higher for Hazeva tomatoes and lower for Ein-Yahav tomatoes and eggplant. Again, the behavioral model corresponds closely with the views of farm advisers, who indicated that tomatoes, onions, and eggplant require about the same level of expenditures while melons requires considerably less. Thus, the estimated allocations based on profit maximization appear inferior to those based on the simple behavioral model both from the

[8] Table 2 reports weighted averages obtained by summing estimated water use over time and farms and dividing by total land allocated to the crop.

standpoints of statistical fit and practical experience.

Distributional Analysis

Because one objective of this paper is to determine variable input allocations among crops, a more complete examination of the predicted allocations is appropriate. The predicted allocations of water and other inputs were derived by each of the models for each farmer, year, and crop. These predictions were then used to form empirical probability density functions of water and other use per dunam. While space constraints prohibit presenting graphical results for all crops, the distribution of predicted water allocations for each model is depicted in figure 1 for bell peppers (the most important crop in each settlement).

Figure 1 illustrates an additional dimension in the comparison of models. The distribution of predictions for the behavioral model (reported in solid lines) is concentrated in a reasonable range as judged by the production norms with no outliers, whereas the profit maximization model has a much wider spread and yields some unreasonable predictions. All of the behavioral model predictions in Hazeva fall within 900 to 2,100 cubic meters per dunam, with virtually all predictions between 1,200 and 1,800; in Ein-Yahav, all predictions fall in the range of 700 to 1,600, with most between 900 and 1,400. By comparison, the profit maximization model pre-

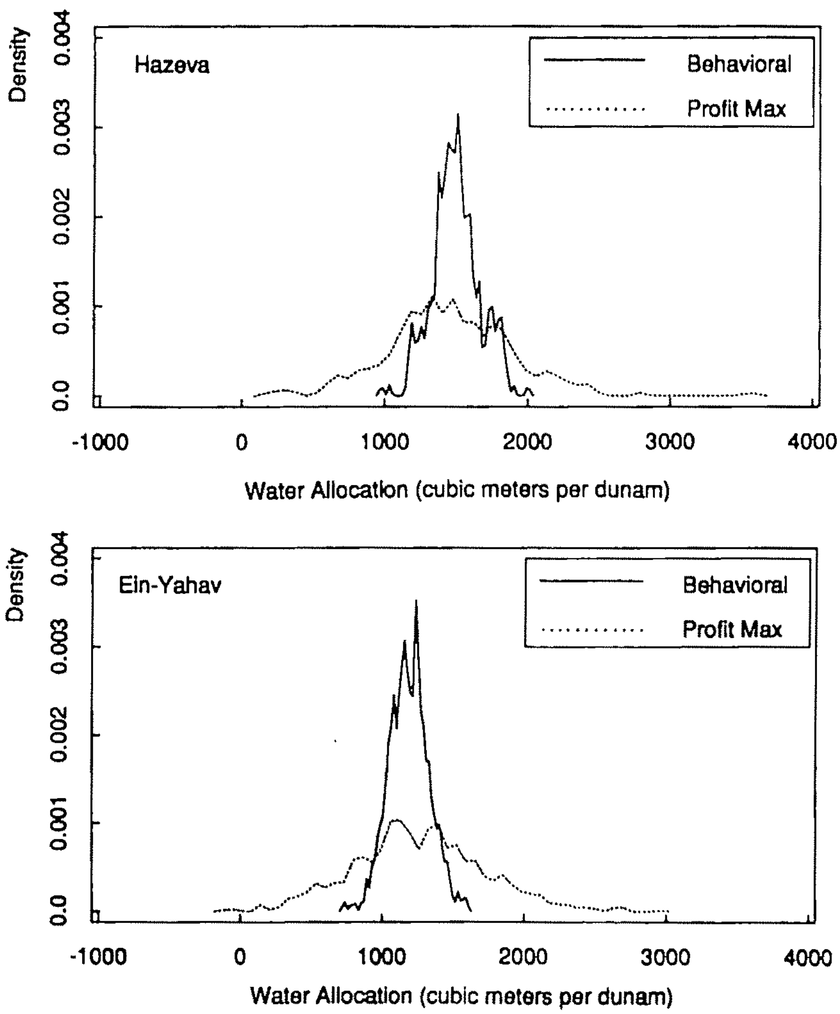

Figure 1. The water allocation distribution for peppers

dicts negative allocations in Ein-Yahav and an unreasonably high level of 3,000 cubic meters per dunam (approximately 10 acre feet per acre) in both settlements.

The results were similar for each of the other crops. However, some of the predictions by the profit maximization model were even more troubling. For tomatoes, the behavioral model predictions were concentrated in in a range of about 700 cubic meters per dunam; however, the profit maximization model predicted substantial activity over a range of 2,000–3,000 cubic meters per dunam. For onions and melons, the profit maximization model indicated substantial concentrations near zero water use, which is unreasonable in the desert conditions of this study. The profit maximization results for eggplant in Ein-Yahav indicated a zero mode of the water use distribution; these results are even more absurd. In contrast, the heavy concentrations predicted by the behavioral model corresponded well to regional norms. The predicted allocations for Ein-Yahav concentrate heavily within the norms reported in table 2. This is plausible because the farm advisers rely more heavily on the older, more established settlement in formulating their norms.

Another purpose of this study was to develop cost accounting information for individual farmers to use in decision making. Because of frequent nonsensical results produced from profit-maximization-based models, farmers considered their predicted allocations useless. On the other hand, the predicted allocations from the behavioral model have been adopted for practical use.

Conclusions

Farm management economists have the problem of allocating variable inputs among crops in formulating enterprise budgets from typical accounting data. The USDA faces similar problems in its legislatively mandated cost of production studies. Using data only on aggregate variable input use and land allocation, this paper suggests a methodology that holds potential for improvement of regional crop budget information. For the sample data used in this study, regressing total input use on land allocations allowing for crop, time, and farmer effects gives an adequate basis for allocating variable input use among crops. By comparison, procedures based on profit maximization are found to yield inferior results.

This paper does not argue that farmers do not pursue profits. Variations in the time coefficients in the behavioral model are likely in response to changes in prices and economic conditions. Similarly, differences in individual coefficients among farmers may at least partially reflect adjustments to increase profitability. Yet, the simple profit maximization model by itself does not seem to provide the best explanation of farmers' observed behavior. Lack of information, limited computational abilities, and the high cost of information gathering and processing (in short, all of the factors that come into play with bounded rationality) may cause the behavior of farmers to be better explained by a simple behavioral model than by a simple profit maximization relationship. If so, then much of the empirical analysis and associated interpretation based on simple profit maximization models may be misleading. This conclusion underscores the challenge to obtain estimable relationships that generalize profit maximization to include informational and data processing limitations and costs.

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Two Practical Procedures for Estimating Multivariate Nonnormal Probability Density Functions

C. Robert Taylor

This article presents two procedures for empirically estimating nonnormal joint probability density functions (pdf's) that are operational with small samples. One procedure empirically estimates marginal distributions. Estimated marginal distributions are then used to transform variates to univariate normality; the transformed variates are assumed to have a multivariate normal distribution. The second approach exploits the identity that a joint distribution is the product of a conditional pdf and a marginal pdf. Conditional and marginal pdfs are individually estimated with this approach. Statistical tests for multivariate normality are also reviewed.

Key words: density estimation, multivariate normality tests, stochastic simulation.

Empirical determination of the probability density function of economic variables is critical in many stochastic analyses. Examples include the evaluation of crop insurance programs, stochastic simulation of firms or the economy, and normative studies based on safety-first or stochastic dominance criteria. For analytical convenience, the normal distribution is often used, although substantive empirical evidence suggests that returns, yields, and many other random variables are not normally distributed (Anderson, Antle, Antle and Goodger, Buccola, Day). Furthermore, sets of random variables, such as crop yields or returns associated with alternative production activities, may be highly correlated.

To overcome the potential biases of stochastic decision analyses based on mean-variance analysis (i.e., normality), Antle suggested a procedure for estimating third and higher moments of univariate or multivariate probability distributions, while Collender and Chalfant suggested an empirical moment-generating function approach. Although the moments uniquely define the probability distribution, it may be infeasible to specify the analytical form of this distribution. For studies based on the moments per se (e.g., a Taylor's series approximation of an objective function), Antle's procedure and the Collender and Chalfant approach are useful. However, a moment-based approach may not be operational for studies that require the probability distribution per se, such as optimization with safety-first or certain stochastic dominance criteria, or stochastic simulations with firm-level or aggregate models.

Several sophisticated nonparametric density estimation procedures have been proposed in the statistical literature, such as kernel estimates (Parzen, Rosenblatt), nearest-neighbor estimates (Loftsgaarden and Quesenberry), and projection pursuit (Friedman, Stuetzle, and Schroeder). These procedures produce an explicit expression of the pdf. However, application of these procedures is severely restricted because convergence requires quite large samples (Duda and Hart, pp. 92–95, 103; Friedman, Stuetzle, and Schroeder, p. 605) which are rarely available in agricultural economics studies. Moreover, pdfs obtained by nonparametric methods are difficult to use in stochastic simulation because the cumulative distribution, which is required for deviate generation, can be obtained only by analytical or numerical integration of the exceedingly complex mathematical expression for the pdf.

This article presents two operational approaches to empirically fit nonnormal joint probability density functions (pdfs) with data from small samples. One method is closely akin to a translation system proposed by Johnson; this approach empirically fits marginal distributions.

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The fitted marginal distributions are then used to transform observations to univariate normality. The set of transformed variates are assumed to have a multivariate normal distribution. A second approach exploits the identity that a joint pdf is the product of a conditional pdf and a marginal pdf. This identity is usually referenced in the case of only two random variables. It can be extended to any number of variates. Conditional and marginal pdfs are individually fitted with this approach.

Both approaches are operational with the small samples often encountered in agricultural economics. Furthermore, the approaches are especially useful in stochastic simulation models because random deviates for the nonnormally distributed random variables can be indirectly obtained from available univariate deviate generators.

The two procedures for fitting multivariate pdfs are presented in this article, and their use in stochastic simulation is discussed. Then, statistical tests for multivariate normality are presented. Empirical estimates of the joint pdf for corn, soybeans, and wheat yields are presented to illustrate the statistical tests and density estimation methods.

The Normal Transformation Approach

One approach to fitting joint pdfs is based on the idea of transforming a set of random variables, (y, x), to another set of random variables, (y', x'), which has a more convenient distribution (Mardia, p. 24). This idea was first proposed by Edgeworth in 1896. However, the particular transformation he proposed was too restrictive, and fitting the transformation by the method of moments was tedious at the time (Mardia, p. 24). A more successful version was developed by Johnson. He proposed the transformation $Z = T(Y)$, where $T(\cdot)$ was of an assumed form (lognormal, logit normal, or inverse hyperbolic sine) and where Z had a normal distribution. The set of transformed variables was assumed to have a multivariate normal distribution. Johnson's three transformations were proposed partly because of their curvature, but largely because they could be analytically manipulated and estimation of associated parameters was practical at the time.

With present computational power, it is no longer necessary to restrict the class of transformations to a small set of assumed forms or restrict the class to those that can be parameterized by a simple approach such as the method of moments. The variable transformation approach can be made more flexible by using any appropriate technique for fitting a marginal pdf; thus, marginal distributions can be fitted arbitrarily well. The fitted marginal distributions may then be used to transform (numerically or analytically) the original observations to univariate normality. The transformed observations can be used in a straightforward way to calculate the correlation matrix for the multivariate normal distribution.

Johnson's class of transformations was restricted because he needed a closed-form inverse transformation. Analytical requirements thus severely restricted the usefulness of Johnson's approach. Although most of the flexible methods for fitting a pdf do not result in a closed-form inverse expression, they are useful because the inverse transformation can be numerically obtained as follows.

Let $FN(y')$ be the cumulative distribution function (cdf) for a standard normal variable, y', and let $F(y)$ be the empirically estimated cdf. For the ith observation on y, the associated transformed observation is given by the root of the equation,

$$F(y_i) - FN(y_i') = 0. \tag{1}$$

The relationship between y_i and y_i' is illustrated in figure 1. Given the untransformed observation, y_o, the empirical marginal pdf is used to find the probability of this or a smaller value of y occurring. This probability is given by F_o in figure 1. Given this value of F, the associated value of the transformed variate, which is y_o', is obtained from the standard normal distribution.

Equation (1) can be solved using one of several numerical techniques for finding roots. Newton's technique, which is based on a linear approximation to (1), is simple and usually works well for this problem.

A closed form approximation for $FN(\cdot)$ can be used to avoid repeated numerical integration of the normal pdf to obtain the cdf used in (1) (see e.g., Taylor 1981, p. 9). Furthermore, a density estimation technique that gives a closed form expression for the distribution function can be used to avoid numerical integration of the empirically estimated pdf. An example of such a method was proposed by Taylor (1984). Other univariate density estimation methods that could be used for fitting marginal pdfs are referenced in Taylor (1984).

Solving (1) for each observation produces a standard normal variate set. This process can be

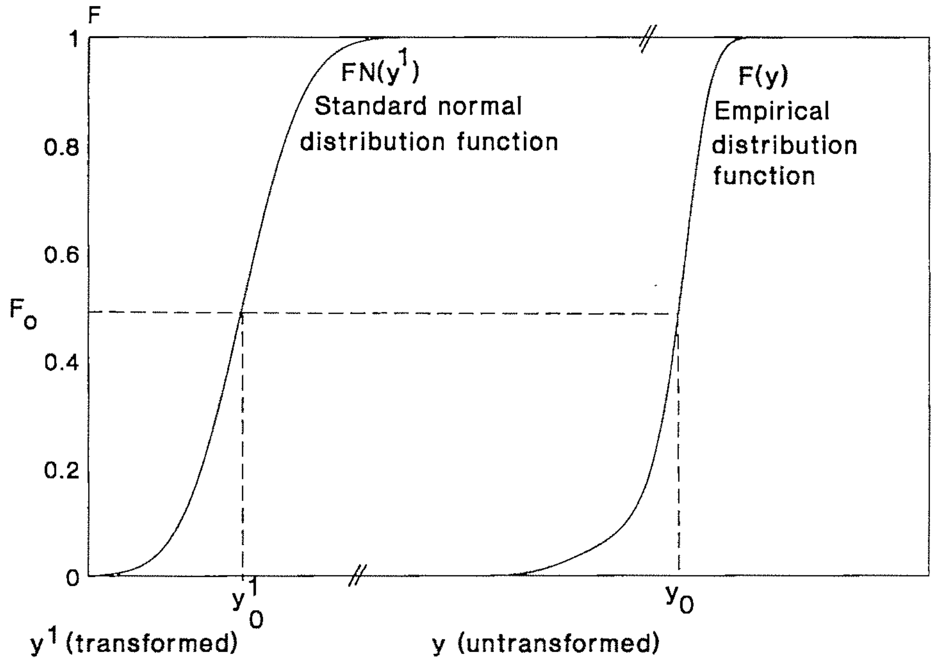

Figure 1. Illustration of the transformation of observations

repeated for each variable. Covariances computed from this data set fully parameterize the multivariate normal distribution which, along with the marginal pdfs for the untransformed data, are assumed to fully characterize the joint pdf of the original variates.

As noted by Mardia, a potential shortcoming of the variable transformation approach is that only one parameter (the correlation coefficient or covariance) describes the interrelationship between each pair of transformed random variables. However, the transformation approach should not be summarily dismissed unless multivariate normality tests of the transformed data indicate a departure from normality. Of course, with small samples, we may not have the luxury of using more than one parameter to characterize variable interrelationships. Furthermore, it is important to note that the method will handle variable interrelationships at least as well as methods in common use.

Use of the Normal Transformation Procedure in Simulation

Use of such a joint pdf in a stochastic simulation model proceeds in reverse from the steps used to obtain the nonnormal pdf. Deviates from a multivariate standard normal deviate generator give values such as y_o' in figure 1 for each variable. The random deviate for the untransformed variate is given by solving (1) for y_o given y_o'. Proceeding in this way for all variates gives the set of deviates for the untransformed (nonnormally) distributed variates obtained from the set of deviates generated by the multivariate normal generator. The availability of multivariate normal deviate generators thus makes the above procedure attractive for simulation.

The Conditional Distribution Approach

Another approach (Duda and Hart, p. 113) to approximating joint pdfs is based on the identity

$$(2)\quad f(y_1, y_2, \ldots, y_d) \equiv f(y_1)f(y_2|y_1)f(y_3|y_2, y_1) \ldots f(y_d|y_{d-1}, \ldots, y_1),$$

where d is the number of jointly distributed random variables. Although the conditional relationships on the right-hand side of (2) could be specified in $d!$ ways, the specification used makes no theoretical difference as long as a sufficiently flexible method is used to empirically fit the distribution.

With the identity approach the number of parameters required to fit the distribution conditioned on the $(d - 1)$ variables may be large relative to the number of observations. However, with many empirical problems, one variable may be dependent on only a few of the other variables, thereby making the approach operational. The method proposed by Taylor (1984) can be used to fit the conditional as well as marginal pdfs in (2).

Use of the Conditional Distribution Procedure in Stochastic Simulation

Generation of stochastic deviates from a joint pdf obtained by exploiting identity (2) must proceed sequentially from obtaining a deviate for the random variable represented by the marginal pdf to a deviate for the random variable represented by the pdf conditioned on all other random variables in (2). Generation of a set of d deviates based on (2) requires d deviates from independent, uniformly distributed random variables. Given such a set of uniformly distributed deviates, generation of deviates for the random variables, y_i, can proceed as follows. A deviate for y_1 can be generated using the cumulative distribution, $F(y_1)$, and a deviate from a uniform distribution. Given this deviate, another uniform deviate can be used with the conditional cumulative distribution, $F(y_2|y_1)$ to obtain a deviate for y_2. This process sequentially continues, culminating with a deviate, y_d, obtained from $F(y_d|y_{d-1}, \ldots, y_1)$ given the deviates $y_1, y_2, \ldots, y_{d-1}$.

Tests for Multivariate Normality

Before empirically fitting distributions to data, it is informative to test whether the data could have been generated by a common theoretical distribution, especially the normal distribution. Statistics commonly used for testing for univariate normality are Pearson's skewness parameter, $b_1^{0.5} = m_3/m_2^{1.5}$, Pearson's kurtosis parameter, $b_2 = m_4/m_2^2$ (Snedecor and Cochran), Geary's kurtosis parameter, $a = mad/m_2$, and the Shapiro-Wilk parameter, $W = c^2/m_2$, where m_i is the ith moment around the mean, mad is the mean absolute deviation, and c is the regression slope of the ordered sample observations on the expected values of the normal order statistics. Buccola discusses use of these statistics in testing for univariate normality of yield, price, revenue and cost series.

Malkovich and Afifi have generalized the Shapiro-Wilk normality test and Pearson's tests for skewness and kurtosis to test the hypothesis of multivariate normality. Machado will be paraphrased to briefly describe the test developed by Malkovich and Afifi. Let the data be $Y_1, Y_2, \ldots, Y_n$, where $Y_i = (y_{i1}, \ldots, y_{ip})'$ is a $p \times 1$ vector of observations. For arbitrary r in the space of all p vectors of unit length, let $\{y_i(r)\} = \{r'Y_i\}$ be the univariate sample obtained by projecting the multivariate sample along r. Directional measures of skewness, kurtosis, and Shapiro-Wilk departure from normality can be obtained, respectively, by computing $b_1(r)$, $b_2(r)$, and $W(r)$ for the univariate projection, $y_i(r)$, of the multivariate sample. Applying Roy's union-intersection principle of test construction to the univariate tests (Malkovich and Afifi) results in the multivariate skewness statistic $b_{1,p} = \max\{b_1(r)\}$, two multivariate kurtosis statistics, $b_{2,p,\max} = \max\{b_2(r)\}$ and $b_{2,p,\min} = \min\{b_2(r)\}$, and the Shapiro-Wilk statistic, $W_{\min} = \min\{W(r)\}$, where each optimization is taken over the unit vector, r.

Optimization required to compute the multivariate test statistics is not a trivial numerical problem. In fact, numerical calculations required to compute accurately the test statistics for several random variables may exceed the numerical calculations required for a simulation model or for an economic optimization model using the joint probability density function. When more than four or five random variables are involved, the task of computing multivariate test statistics or relying on univariate test statistics along with visual inspection of scatter plots is an onerous one. Theoretical considerations would dictate that all statistics are computed, while practical (time, resources, and so forth) considerations in empirical analyses might dictate the latter choice.

With two or three variates, a fine grid search is practical for computing multivariate test statistics. However, with more variates, more systematic numerical search techniques could be employed.

Machado has given a method for calculating approximate percentage points of the distribution of the above multivariate normality test statistics. Simulation studies in Machado show that the approximations are good for sample sizes of 25 and above for dimensions of 2, 3, and 4; however, accuracy of the approximation for p greater than 4 has not been examined.

Monte Carlo studies show that with small samples the power of the tests for $p = 2$ is adequate, but not high, against some alternatives (Malkovich and Afifi). Like univariate tests (Buccola), however, there is great risk in not detecting nonnormality with the small sample sizes, say 10 to 50, often encountered in empirical research.

Empirical Application

Univariate and multivariate test statistics for linearly detrended corn, soybean, and wheat yields in Macoupin County, Illinois, for the 1945–87 period are given in table 1. Test statistics distinctly show univariate and multivariate skewness, kurtosis, and nonnormality in the data set. Test statistics for univariate and multivariate normality computed from logarithmically transformed yield data are also highly significant.

The joint pdf of linearly detrended per acre yields of corn, soybeans, and wheat was fitted to illustrate the two procedures. A polynomial approximation of the cumulative distribution (cdf) constrained to the zero-one range by a hyperbolic tangent (Taylor 1984) was used to fit all marginal and conditional pdfs required with the two approaches. The form of the conditional cdf is

$$(3)\quad F(y_j|y_{j-1}, \ldots, y_1) = 0.5 + 0.5*\tanh(P(y_j, y_{j-1}, \ldots, y_1)),$$

and the associated conditional pdf is

$$(4)\quad f(y_j|y_{j-1}, \ldots, y_1) = 0.5*P^j(y_j, y_{j-1}, \ldots, y_1) *\text{sech}^2(P(y_j, y_{j-1}, \ldots, y_1)),$$

where $P(\cdot)$ is a polynomial function, P^j is the partial derivative of $P(\cdot)$ with respect to y_j, $\tanh(\cdot)$ is the hyperbolic tangent, and $\text{sech}(\cdot)$ is the hyperbolic secant. Parameters characterizing $P(\cdot)$ are estimated by maximum likelihood applied directly to the log-likelihood function based on (4).

The polynomial approximation was restricted to a cubic function for the empirical application because the cubic provides a reasonably accurate approximation of most unimodal pdfs. A self-contained computer program for maximum likelihood estimation of the pdf for the cubic approximation is available from the author. Theoretical and practical limitations of the procedure are discussed in Taylor (1984).

The Normal Transformation

Maximum likelihood estimates of the marginal pdfs for corn, soybeans, and wheat are given in table 2. The Schwarz model selection criterion was used to determine which cubic terms to include in the final model. Experience in applying the hyperbolic tangent approach to many data sets shows use of the Schwarz criterion to be generally consistent with addition or deletion of individual polynomial terms based on asymptotic t-values.

The procedure outlined in figure 1 and equation (1) was used to transform the raw detrended crop yield observations to univariate standard normality based on the fitted marginal pdfs in table 2. Univariate test statistics for normality shown in table 3 do not reject normality of the transformed data, which suggests that the marginal distributions in table 2 fit the data reasonably well.

Table 1. Univariate and Multivariate Tests of Distributional Shape Based on Detrended Macoupin County, Illinois Crop Yield Data, 1945–87

Random Variable	Skewness b_1	Kurtosis b_2	Kurtosis a	Normality W
UNIVARIATE TESTS				
Corn	−1.40***[a]	6.05***	0.73**	0.90***
Soybeans	−1.46***	5.81***	0.77	0.88***
Wheat	1.80***	9.33***	0.69***	0.87***
MULTIVARIATE TESTS				
All	−1.84***	9.43 (max)*** 2.29 (min)		0.87 (min)***

[a] One, two, or three asterisks denote statistical significance at the 10%, 5%, or 1% level, respectively. Critical values for b_1 and b_2 were computed from approximation formulas given in Machado; critical values of a were obtained from Geary; and critical values of W were obtained from Shapiro and Wilk.

Table 2. Hyperbolic Tangent Approximation of Marginal Probability Functions for Corn, Soybeans, and Wheat Yield

Crop	Maximum Likelihood Estimate of[a] β_1	β_2	β_3	β_4
Corn	−0.1308	2.9497	0.8182	
	(0.97)	(7.83)	(2.47)	
Soybeans	−0.2458	2.3501	1.7590	0.7614
	(1.71)	(7.33)	(2.95)	(1.82)
Wheat	0.1042	1.3140	−0.137299	
	(0.79)	(7.76)	(2.61)	

Note: Distributions were fitted to deviations from an OLS linear trend model. Deviations from the trend were scaled (multiplied) by 0.02, 0.10, and 0.10 for corn, soybeans, and wheat, respectively, to avoid numerical difficulties in obtaining maximum likelihood estimates of the parameters of the pdf.

[a] The form of the distribution function, $F(y)$, is

$$F(Y) = 0.5 + 0.5 * \text{TANH}\,[\beta_1 + \beta_2 Y + \beta_3 Y^2 + \beta_4 Y^3].$$

The associated probability density function $F(Y)$ is

$$f(Y) = 0.5 * (\beta_2 + 2\beta_3 Y + 3\beta_4 Y^2) * \text{SECH}^2\,[\beta_1 + \beta_2 Y + \beta_3 Y^2 + \beta_4 Y^3].$$

Asymptotic t-values are given in parentheses.

Transformed data were used to estimate the correlation matrix given in table 4. Since the standard normal cdf was used in equation (1), the transformed variates have mean zero and variance one. The transformed variable correlation matrix in table 4 along with the marginal pdfs given in table 1 completely characterize the multivariate nonnormal crop yield probability density function obtained using the transformation approach.

Multivariate test statistics for the transformed data set, which are shown in table 3, show marginal significance at the 5% level for skewness (max b_1), and significance at the 10% level for kurtosis (min b_2). The nonnormality (min w) test was not significant. A comparison of the multivariate test statistics shown in table 1 (untrans formed data) with multivariate test statistics i table 3 (transformed data) weakly suggests tha a single parameter (the correlation coefficien may not be sufficient to describe the interrela tionship between the transformed variates in thi particular case. However, comparison of statis tics in tables 1 and 3 clearly reveals that for th given sample of yield data, the transformatio procedure results in a joint pdf that is better tha the multivariate normal pdf; thus, use of th normal transformation procedure results in les bias in this empirical example than use of th multivariate normal distribution for the raw data

The Conditional Distribution Approach

Consider now an application of the identity ap proach to fitting a joint distribution for cro yields. The hyperbolic tangent approximation t pdfs for each yield variable conditional on th other two yield variables was considered. Esti mates with asymptotically significant coeffi cients are shown in table 5. Only corn and soy bean yield distributions were significantly relatec which is consistent with the low correlation (table 4) of wheat and soybean yields, and whea and corn yields.

Comparison of Empirical Fits

In comparing alternative empirical fits of join pdfs, statistical tests should be conducted to de termine which fitted pdfs are significantly bette than others. With the present state of develop ment of nonnested hypothesis tests, however, test with well-understood small sample proper ties is not available (Judge et al., p. 885). Thus the alternatives can only be ranked using value of the likelihood function or using an informa

Table 3. Univariate and Multivariate Tests of Distributional Shape of Data Transforme to Univariate Normality Based on Empirically Fitted Marginal Distributions Given in Table

Random Variable	Skewness b_1	Kurtosis b_2	Kurtosis a	Normality W
UNIVARIATE TESTS				
Corn	−0.39	2.65	0.81	0.97
Soybeans	−0.20	2.64	0.85*	0.98
Wheat	0.30	3.35	0.79	0.98
MULTIVARIATE TESTS				
All	−0.66**	3.57 (max)		0.95
		2.16 (min)*		

Table 4. Correlation Matrix for Yield Observations

	Corn	Soybeans	Wheat
Raw observations:			
Corn	1.0000		
Soybeans	0.8503	1.0000	
Wheat	0.1756	0.1876	1.0000
Transformed observations:			
Corn	1.0000		
Soybeans	0.8017	1.0000	
Wheat	0.2063	0.2099	1.0000

Table 5. Hyperbolic Tangent Approximation of Conditional Probability Functions for Corn and Soybean Yield

	Maximum Likelihood Estimate of[a]			
pdf	β_1	β_2	β_3	β_5
$f(Y_{co}\|Y_{sb})$	−0.1412	5.1959	0.8579	−3.3314
	(0.97)	(7.80)	(1.66)	(6.04)
$f(Y_{sb}\|Y_{co})$	0.0236	4.0066		−4.3335
	(0.18)	(7.90)		(6.26)

[a] The form of the pdf is

$$f(Y_i|Y_j) = 0.5 * (\beta_2 + 2\beta_3 Y_i + 3\beta_4 Y_i^2) * \text{sech}^2 (\beta_1 + \beta_2 Y_i + \beta_3 Y_i^2 + \beta_4 Y_i^3 + \beta_5 Y_j),$$

with $i \neq j$, and with *co* designating corn and *sb* designating soybeans.

tion criterion, such as the Schwarz criterion. Joint probability density functions for the crop yield variables fitted with various approaches are compared in table 6. Relative ranking of the models based on the value of the likelihood function from worst to best is univariate (independent normality), multivariate normality, the conditional distribution approach with soybean yield conditioned on corn yield, the transformation approach, and the conditional distribution approach with corn yield condition on soybean yield. Relative ranking of the models using the Schwarz criterion was the same, except that both conditional distribution fits were better than the transformation approach. The Schwarz criterion penalized the larger number of parameters used in the transformation approach compared to the conditional approach.

Concluding Comments

This article presents two procedures for empirically fitting multivariate nonnormal probability density functions. One procedure transforms variates to multivariate normality based on fitted marginal pdf's, while the second procedure exploits a fundamental identity in probability theory that a joint distribution is the product of a marginal and a conditional probability density function. Both procedures are small sample alternatives to assuming a particular theoretical distribution for empirical analyses. Either procedure will work at least as well as any methods commonly used.

Implementation of the procedures results in a closed form expression of the distribution function and the probability density function. Each procedure can be adapted for generation of deviates for use in stochastic simulation.

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Table 6. Comparison of Alternative Estimates of the Joint pdf of Corn, Soybeans, and Wheat Yields

Model	ln (Likelihood) for Sample Data	Number of Parameters	Schwarz Model Selection Criterion
Independent normal	−89.39	6	−100.67
Multivariate normal	−60.99	9	−77.92
Multivariate normality using transformation approach[a]	−48.93	13	−73.39
Conditional identity:			
$f(Y_{co}\|Y_{sb})f(Y_{sb})f(Y_{wh})$	−47.38	10	−66.19
$f(Y_{sb}\|Y_{co})f(Y_{co})f(Y_{wh})$	−52.05	9	−68.98

[a] Applying standard theorems for obtaining the multivariate distribution of a set of functions of random variables, it can be shown that the likelihood function for the transformation approach is

$$l = \frac{f(Y_{co})}{fn(Y_{co})} \frac{f(Y_{sb})}{fn(Y_{sb})} \frac{f(Y_{wh})}{fn(Y_{wh})} \cdot g(Y'_{co}, Y'_{sb}, Y'_{wh}),$$

where l is the likelihood function, $g(\cdot)$ is the multivariate normal pdf, $f(\cdot)$ are the appropriate fitted marginal pdfs, $fn(\cdot)$ is the univariate normal pdf, Y_i are the untransformed variables, and Y'_i are the transformed variates.

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Impact of the WIC Program on Food Expenditures

Gustavo J. Arcia, Luis A. Crouch, and Richard A. Kulka

Participation in the WIC program tends to shift grocery expenditures in favor of more nutritious food. Dairy data show that WIC women consumed more nutrient-dense foods than non-WIC women. WIC women and their families spent significantly less on meals away from home than control families, suggesting a more efficient use of the food budget. WIC's impact on unintended recipients is negligible, while its impact on foods for WIC children is positive and highly significant. Recall data on monthly food expenditures indicate that total food expenditures and grocery expenditures did not increase as a result of program participation.

Key words: food diary, food expenditures, WIC, WIC children, WIC foods.

The Special Supplemental Food Program for Women, Infants, and Children (WIC) is a federally sponsored program designed to provide supplemental food and nutrition education to low-income, nutritionally at-risk participants. The program serves over 3.4 million persons monthly at an annual cost of over $1.5 billion (fiscal year 1987 program data). Program participation is limited to pregnant women, post-partum women (up to six months after delivery), breast-feeding women (up to twelve months after delivery), infants (up to one year of age), and children (up to five years of age) from low-income families who are determined by a competent health professional to be nutritionally at risk. In addition, applicants must have a gross family income not exceeding 185% of the Office of Management and Budget nonfarm income poverty guidelines. Participation in other income assistance programs such as Food Stamp or School Lunch Programs does not affect eligibility.

WIC foods provide nutrients that are likely to be lacking in the diet of participants, particularly high-quality protein, iron, calcium, vitamin A, and vitamin C. The food prescription, known as a food package, contains food such as infant formula, milk or milk products, iron-fortified cereal, juice, eggs, and dried beans or peanut butter. It may be tailored to a participant's needs within federal guidelines, and it may vary in value between $28 and $32 per month on average.

This study analyzes the effects of program participation on expenditure and consumption patterns by the households involved. This food expenditures study originally was developed as a part of the *National WIC Evaluation* commissioned by the Food and Nutrition Service of the U.S. Department of Agriculture (USDA). Data for the evaluation were collected in 1983, and a comprehensive final report was published in 1986.

Data Collection Design and Methods

The *National WIC Evaluation* study combined recall and diary methods to collect information on household food expenditures, thus permitting longitudinal and cross-sectional comparisons between WIC and non-WIC households. The study sample was the nationally representative probability sample of pregnant women enrolled in WIC and the control group of non-WIC pregnant women in the *Longitudinal Study of Pregnant Women*.[1]

Data collection proceeded as follows: During the initial clinic enrollment interview, 4,219 WIC and 785 non-WIC women were asked to recall their monthly expenditures for food and bever-

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[1] *The Longitudinal Study of Pregnant Women* was one of the four component studies of the *National WIC Evaluation*. The others were the *Food Expenditures Study*, the *Historical Study of Pregnancy Outcomes*, and the *Study of Infants and Children*.

ages for the month immediately preceding the interview. This is referred to as "time 1" in the following discussion. The questions used were comparable to those previously developed and used in the *U.S. Quarterly Consumer Expenditure Surveys* and the *Canadian Family Food Expenditure Surveys*.[2] These questions were repeated during the second interview, late in the pregnancy ("time 2").

At the second interview, in addition to the recall assessment of food expenditures, a random sample of 1,031 WIC and 551 non-WIC women kept a detailed diary of food purchases for a one-week period following the visit, using a ledger diary similar to those employed in the U.S. and Canadian surveys. A portion of the second interview focused on the use of the diary. A monetary incentive was offered for participation in this phase of the study.

An interviewer collected the diary in a home visit in order to encourage a high level of cooperation and complete reporting. The interviewer thoroughly checked the diary for consistency and completeness, using a set of "diary check" questions for types of expenses typically forgotten, and attempted to obtain—by retrospective interview—information for days not recorded in the diary. Along with intake and expenditures data, major predictors or correlates of family food expenditures, such as family size, age-sex household composition, and household income were collected.[3]

Because diary information was recorded and collected only at the time of the second interview, a longitudinal analysis based on these data is not possible. However, the data are especially useful for comparing WIC and non-WIC households because of the greater detail they provide about the types of foods purchased. Specifically, diary data may be used to examine changes in food purchasing behavior by comparing the portion of food dollars allocated by WIC and non-WIC diary-keeping families to various types of food.

The inferences that can be drawn from this study are limited in several ways. The study emphasizes the impact on pregnant women participating in the WIC program. As in all surveys, the data are subject to measurement errors and to the families' accuracy in reporting income and food purchases. Another limitation is the lack of information on the quantity and composition of foods purchased with the WIC coupons. Because the coupons are valid for nutrient-equivalent foods, a WIC woman may, for example use her coupons to buy cheese and milk in different combinations. As a result, the data do not allow for an exact determination of the composition of the WIC package because most WIC foods would overlap with foods normally purchased for the rest of the household.

The use of recall and diary methods was intended to test the effects of WIC on food expenditures and on the consumption of foods promoted by the WIC program (WIC-type foods). However, these two methods cannot be used to cross-check dietary consumption information. The recall method is a proven, cost-effective way of gathering information about food-purchasing patterns that closely approximates actual average intake over a predefined period (Adelson; Burk and Pao). However, actual consumption could be underestimated (Madden, Goodman, and Guthrie) or actual food expenditures could be overestimated (Quackenbush and Schaeffer). Diary methods are more costly but yield more detailed data about intake by food groups. However, diary methods have biases as well. Burk and Pao found that diary estimates differed substantially from recall methods. Correlation coefficients among diary and recall methods generally are about 0.7 (Balogh, Kahn, and Medalie). In general, diary records are not representative of average long-term intake because of weekly fluctuations in the family's purchasing patterns (payday effect), recording inaccuracies, or diary-induced modifications in the types of foods consumed by the family (Burk and Pao). The correlation between diary and recall data to measure food expenditures in this study is approximately 0.49.

Despite the shortcomings outlined above, diary and recall methods remain the most cost-effective ways to collect data on food purchasing from large samples.

Estimation Procedure

The empirical model for the recall data attempts to measure the following impacts of the WIC program: (*a*) effect of WIC benefits on monthly food expenditures, (*b*) degree to which WIC benefits substituted for foods that would have been purchased anyway, and (*c*) degree to which WIC benefits were shared by nonintended ben-

[2] A complete list of the questions used is available from the authors or may be found in volume IV, appendix VII-A, of the *National WIC Evaluation*.

[3] Throughout the study the term "household" is assumed to mean a group of people who, regardless of relationship, share resources and liabilities. A household may group more than one family.

eficiaries in the family. A two-stage least squares model was developed with variables which were significant in similar nutritional assistance programs such as the Food Stamp Program and the National School Lunch Program (Adrian and Daniel; Blaylock and Smallwood; Basiotis et al.; Akin, Guilkey, and Popkin; Chen; Basiotis).

The empirical model for the diary data estimates the impact of WIC on food expenditures by food types. The food types selected for the diary analysis are a basket of foods generally found in the WIC package (WIC-type foods), meats, cereals and bakery products, vegetables, other fresh foods, and frozen foods. In addition to the food groups listed above, the diary data analysis also examines weekly expenditures on food, groceries, and meals away from home. Diary data are analyzed with ordinary least squares since they were only collected for time 2.

The impact of WIC on food expenditures using recall data is estimated by the following two-stage least squares model:

$$\begin{aligned} FE2 &= h_0 + h_1 FE_1 + h_2 W \\ &\quad + h_3 C + h_4 A + h_5(W^*C) \\ &\quad + h_6(W^*A) + lX + u, \\ FE1 &= f_1 + f_2 Y + gM + e, \end{aligned}$$

where $FE2$ is food expenditures at time 2; $FE1$, food expenditures at time 1; h_i, l, f_i, g, regression coefficients ($i = 1, \dots n$); $W = 1$ for WIC women, 0 for non-WIC women; C, number of children in the household; A, number of adults in the household including the WIC woman; X, vector of family composition and participation in other assistance programs; Y, monthly household income, as defined in the following section; M, a vector of socioeconomic characteristics including ethnicity, participation in other assistance programs, and education level of the WIC woman; and u, e are disturbances.

The empirical model for the diary data is

$$\begin{aligned} FG_i &= d_0 + d_1 Y + d_2 W + d_3 C + d_4 A \\ &\quad + d_5(W^*C) + d_6(W^*A) + lX + v, \end{aligned}$$

where FG_i is food group i ($i = 1, \dots, m$); d_j, regression coefficient for variable j ($j = 1, \dots, n$); and v, disturbance.

Coefficient h_2 in the model for recall data measures the impact of WIC participation by a pregnant woman on total household food expenditures. Coefficients h_3 and h_4 measure the effect of an extra child or adult on expenditures, and coefficients h_5 and h_6 measure the impact on food expenditures of each extra child and adult, respectively, whenever a WIC woman is in the household.

Coefficients h_3 and h_4 are expected to be large and statistically significant because household size is a main determinant of household food expenditures. Coefficients h_5 and h_6 would be statistically significant only if women's participation in the WIC program affected the impact of other adults and children on total family food expenditures over and above normal circumstances. Thus, h_5 and h_6 represent an indirect estimation of the sharing of WIC benefits by other family members. Direct sharing of WIC foods could not be estimated because intrafamily allocation of food was beyond the scope of the *National WIC Evaluation*.

The total sharing of food expenditures coming from WIC can be estimated by

$$Sharing = h_5{}^*C + h_6{}^*A,$$

where C and A represent the number of children and adults in the household, respectively. Because h_2 is the measure of the WIC program's actual impact, substitution must equal the total WIC transfer (the intended impact), *WIC*, minus sharing:

$$Substitution = WIC - (h_2 + h_5{}^*C + h_6{}^*A).$$

Since the exact value of the WIC package is not available, substitution can be approximated by replacing the value *WIC* with the range of package values reported for the WIC package (between \$28 and \$32).

The substitution and sharing of WIC benefits are entirely economic and are based on indirect evidence. Adjusting for expenditures at time 1 in the equation for $FE2$ is important. If, for example, families of WIC recipients spend more on food than other families and $FE1$ were not in the equation for $FE2$, the pre-existing difference in expenditures levels between WIC recipients and other families would be attributed improperly to the WIC program.

Definition of Variables

Food expenditures for the recall data are the sum of all reported expenditures on foods reported in the time 1 and 2 interviews. These expenditures were obtained by a trained interviewer who helped participants recall monthly expenditures on food and nonfood items bought at supermarkets, convenience stores, wholesale outlets,

restaurants, vending machines, and other food sources.

Total household income in the recall data is the sum of wage and nonwage income received by all household members. Nonwage income includes social security, unemployment insurance, food stamps, and other family assistance programs received during time 1. No information on household income at time 2 was collected. Therefore, total income does not include the value of the WIC coupons. Moreover, the exact market value of the WIC coupons is not available because they are exchanged directly for food by the WIC participant. Total income for the diary data is equal to total income at time 1 minus the value of food stamps, which are included as a separate variable in the diary analysis.

Family composition accounts for the number of infants, children between 1 and 5, 5 and 10, and 11 and 21 years of age, and the number of adults. All groups are classified by sex. Ethnicity is defined by categorical variables with a value of 1 if the respondent is white, black, and hispanic. Other ethnic groups (i.e., Asian, Pacific islander) take a reference value of 0.

The variable *Male Head Present* is used to represent civil status. This variable takes a value of 1 if a husband or male companion lives in the house and a value of 0 otherwise. Education of the WIC woman is a categorical variable with a value of 1 if the respondent completed elementary school, high school, junior high school, or post-high school. The reference value of 0 is for women who did not complete elementary school. *Lunch Program* is defined as the number of children in the household who participate in a school lunch program. *Number of Guests* is defined as the number of person/days of household guests during the month prior to the interview at times 1 and 2. The variable *Food Stamps* is categorical in the recall analysis, taking a value of 1 if anybody in the household was a food stamp recipient and 0 otherwise. In the diary analysis the variable *Foods Stamps* equals the net value of food stamps received by the household. The variables *Other WIC Women, WIC Infant,* and *WIC Child* represent the number of other women, the number of infants and the number of children in the household receiving WIC coupons.

Sample Characteristics

The study's basic sample population contains 4,219 WIC participants and 785 non-WIC participants. From this sample, a subsample of 1,031 WIC women and 551 non-WIC women was obtained for the diary data on food purchases. Characteristics of these samples are summarized in tables 1 and 2, with standard errors in parentheses.

In general, non-WIC families have higher total family incomes, and education levels and racial distribution differ as well between non-WIC and WIC families. Non-WIC families are better educated with a higher proportion of pregnant women having high school educations than in WIC families. The proportion of whites among non-WIC families is higher than among WIC families.

WIC families in the recall sample reported significantly less total food expenditures than the non-WIC families. They spent significantly less on meals away from home, and had larger food stamp allotments (see table 1). The WIC families in the diary sample reported significantly greater grocery expenditures and purchases of WIC-type foods than non-WIC families at time 2.[4] Expenditures on meals away from home were also significantly less for the WIC diary sample families (see table 2). However, no significant differences between the two family groups were found in expenditures on the other food categories.

The higher expenditure levels for WIC-type foods found among WIC families cannot be attributed to program participation alone because no diary measures exist at time 1 prior to initial enrollment in the WIC program.

Model Results

The results from the recall data (table 3) indicate that household composition is the primary determinant of total food expenditure; the coefficients associated with family composition are significant. Other important variables which increase household food expenses are the number of guest-days during the month prior to the interview and participation in the food stamp program. However, participation in the school lunch program significantly reduces food expenditures. Finally, food expenditures are unaffected by schooling, ethnicity, or the presence of a male head of household. Grocery expenditures are also determined by family composition. The regression results for grocery expenditures also show

[4] Since the exact composition of the WIC package is left at the discretion of the participant, the term "WIC-type foods" is used to describe or approximate purchases made with WIC coupons.

Table 1. Selected Socioeconomic Characteristics of WIC and Non-WIC Families in the Food Expenditures Recall Sample

	WIC n = 4,219		Non-WIC n = 785	
Variables	Time 1	Time 2	Time 1	Time 2
Total family income ($/month)	582.04 (6.29)[a]		739.38 (19.96)	
Total food expenditures ($/month)	199.77 (1.92)	210.04 (1.92)	213.98 (4.67)	223.15 (5.10)
Grocery expenditures ($/month)	160.64 (1.42)	170.67 (1.44)	166.12 (3.37)	171.21 (3.53)
Meals away from home ($/month)	11.73 (0.37)	12.37 (0.37)	21.91 (0.98)	21.19 (0.98)
Food stamps ($/month)	66.56 (1.43)	70.02 (1.42)	34.44 (2.48)	35.36 (2.44)
No. of children (1–5 years of age)	0.63 (0.01)		0.55 (0.03)	
Number of adult family members (including WIC women)	1.98 (0.03)		1.89 (0.05)	
Ethnicity (% of total)				
Whites	49.08 (0.77)		56.90 (1.77)	
Blacks	31.19 (0.71)		19.20 (1.40)	
Hispanics	17.91 (0.59)		21.40 (1.46)	
Education of women (% of sample)				
1–6 years	4.17 (0.31)		1.52 (0.44)	
7–8 years	8.22 (0.42)		6.11 (0.86)	
9–11 years	42.87 (0.76)		34.52 (1.70)	
12 years or more	34.13 (0.73)		42.54 (1.77)	

Source: Food Expenditures Recall Sample.
Note: A blank indicates not measured.
[a] Standard errors of means are in parentheses.

Table 2. Selected Socioeconomic Characteristics of WIC and Non-WIC Families Who Kept A Diary of Food Consumption

Variables	WIC n = 1,031	Non-WIC n = 551
Total income for diary week ($)	140.75 (3.16)	175.06 (4.38)
Number of children 1–5	0.61 (0.02)	0.54 (0.03)
Number of adults family members (including WIC women)	1.95 (0.05)	1.87 (0.06)
Food stamps ($/week)	16.30 (0.64)	7.94 (0.65)
Ethnicity (% of sample)		
Whites	50.72 (1.56)	56.98 (2.11)
Blacks	29.00 (1.41)	17.60 (1.62)
Hispanics	18.52 (1.21)	23.41 (1.81)
Education of women (% of sample)		
1–6 years	3.29 (0.56)	1.63 (0.54)
7–8 years	8.34 (0.86)	5.08 (0.93)
9–11 years	43.45 (1.54)	34.66 (2.02)
12 or more years	33.36 (1.46)	43.01 (2.11)
Expenditures by food group ($/week) WIC-type foods[a]	1.276 (0.38)	8.13 (0.26)
Meat	15.27 (0.51)	15.11 (0.75)
Condiments	6.09 (0.21)	6.00 (0.26)
Cereals and breads	6.86 (0.18)	7.14 (0.23)
Fresh foods (e.g., fresh fruits)	20.35 (0.59)	21.15 (0.79)
Frozen foods (e.g., frozen vegetables)	4.14 (0.24)	3.58 (0.24)
Vegetables (neither fresh nor frozen)	7.65 (0.24)	7.11 (0.29)
Dairy	1.59 (0.10)	1.46 (0.08)
Beverages	4.09 (0.14)	4.07 (0.19)
Others	0.09 (0.01)	0.10 (0.02)
Total food expenditures ($/week)	64.06 (1.33)	62.85 (1.68)
Grocery expenditures ($/week)	54.44 (1.21)	49.15 (1.52)
Meals away from home ($/week)	9.61 (0.38)	13.69 (0.69)

Note: The term WIC-type foods refers to all foods contained in the WIC package plus the same type of foods purchased with the family's own funds.
Source: Food Purchase Diary Sample.
[a] Standard errors of means are in parentheses.

Table 3. Impact of WIC Participation on Monthly Food Expenditures

Selected Independent Variables	Dependent Variables ($/month)					
	Total Food Expenditures Time 2	Total Food Expenditures Time 1	Grocery Expenditures Time 2	Grocery Expenditures Time 1	Meals Away from Home Time 2	Meals Away from Home Time 1
Intercept	136.08***[a]	89.42***	109.35***	70.93***	11.71***	8.84**
	(7.78)	(12.40)	(5.52)	(8.75)	(1.74)	(3.46)
Total income		0.062***		0.037***		0.012***
		(0.004)		(0.003)		(0.001)
Total food expenditures at time 1 (*h*1)	0.16***		0.12***		0.51***	
	(0.03)		(0.03)		(0.06)	
Children (*h*3)	27.79***		24.91***		−1.18	
	(5.55)		(3.92)		(1.38)	
Children 0–5		18.27***		16.25***		−1.028
		(2.57)		(1.81)		(0.72)
Children 5–10		35.09***		27.94***		−0.19
		(2.78)		(1.96)		(0.77)
Males 11–22		38.00***		29.82***		1.43*
		(2.73)		(1.93)		(0.76)
Males 23+		42.92***		33.52		1.34
		(3.84)		(2.71)		(1.07)
Females 11–22		33.86***		24.85***		1.69*
		(3.00)		(2.12)		(0.84)
Females 23+		24.72***		18.02***		1.76*
		(3.45)		(2.43)		(0.96)
Adults (*h*4)	41.19***		28.53***		2.90***	
	(2.75)		(1.94)		(0.65)	
Male head present		−6.36		−1.37		−0.79
		(4.96)		(3.5)		(1.38)
White		0.26		−2.25		1.51
		(11.58)		(8.17)		(3.23)
Black		−16.18		−18.08**		0.42
		(11.78)		(8.32)		(3.29)
Hispanic		−17.92		−7.34		−2.16
		(11.92)		(8.41)		(3.33)
Education 1–6		15.04		27.49***		−8.19***
		(10.10)		(7.13)		(2.82)
Education 7–8		−2.22		2.68		−5.82***
		(7.92)		(5.59)		(2.21)
Education 9–11		−10.18*		−2.92		−4.94***
		(5.59)		(3.94)		(1.56)
Education 12		−7.23		−2.04		−2.19
		(5.56)		(3.92)		(1.55)
WIC (*h*2)	−9.59		−3.90		−5.16***	
	(6.12)		(4.31)		(1.55)	
WIC*children (*h*5)	−6.83		−7.05		1.09	
	(6.13)		(4.31)		(1.55)	
WIC*adults (*h*6)	−10.37***		−3.08		−1.86*	
	(2.76)		(1.94)		(0.69)	
Lunch program	−0.02	−0.87**	−0.08	−0.35	0.04	−0.11
	(0.33)	(0.31)	(0.23)	(0.22)	(0.08)	(0.08)
Guests	16.62***	16.76***	17.45***	13.31***	−1.88	−2.40*
	(5.07)	(4.9)	(3.57)	(3.46)	(1.28)	(1.37)
Food stamps	0.10***	0.17***	0.12***	0.17***	−0.03***	−0.02***
	(0.02)	(0.02)	(0.01)	(0.01)	(0.005)	(0.006)
Other WIC women	7.12	9.11	1.55	7.81	1.28	−2.31
	(6.13)	(13.74)	(4.32)	(9.70)	(1.55)	(3.83)
WIC infant (1–12 months)	−15.59		−8.80		0.36	−2.70
	(10.34)		(7.22)		(2.61)	(2.39)
WIC child (1–5 years)	6.63		7.75*		−0.04	0.52
	(4.46)		(3.14)		(1.12)	(1.39)
Sample size	5004	5004	5004	5004	5004	5004
R^2		0.35		0.40		0.07
F	172.64	121.06	216.85	151.80	28.33	17.96

Source: Food Expenditures Recall Sample.
[a]Triple asterisk indicates $p < 0.001$; double asterisk indicates $p < 0.01$; and single asterisk indicates $p < 0.05$.

a positive impact of elementary education and significantly lower grocery expenditures associated with black households.

Table 3 also show the coefficients which represent substitution and sharing. The WIC coefficients for total food expenditures and grocery expenditures are not significantly different from zero, indicating no apparent increase in total food expenditures resulting solely from participation in the WIC program by women.

The recall data also show that the interaction term *WIC*adults* is negative and highly significant. Thus, the presence of each additional adult in a WIC household appears to reduce monthly total food expenditures. This significant interaction effect may be explained by the impact of WIC on meals eaten out because the difference between total food expenditures and grocery expenditures is mostly explained by expenditures on meals away from home. The last two columns in table 3 show the recall data results from expenditures on meals away from home. These results show that WIC program participation is strongly associated with a tendency to spend less on meals away from home. Families of pregnant women participating in WIC are estimated to spend $6.26 less per month on meals eaten out than the families of non-WIC women. Apparently WIC program participation contributes to a larger proportion of home-cooked meals in the family diet. Because meals away from home have an implicit cost for service that increase the cost per unit of nutrients compared to home-cooked meals, the WIC program fosters a more efficient use of the family's food budget.

Impact of WIC on Food Expenditure Patterns

The results for the recall data reflect program impact only in terms of food expenditures. This is only a partial indicator of overall program performance. It is possible, for example, to have different food consumption patterns between two time periods and still have data showing equal food expenditures. Hence, the impact of the WIC program on both food expenditures and food purchase patterns must be examined.

Table 4 presents the OLS regression results for the diary data. The columns in the table represent different food groups reported in the diary. The diary results show that participation in the WIC program has a positive impact on expenditures on WIC-type foods and a negative impact on expenditures for meals away from home. These combined results indicate that WIC has a beneficial impact on the quality of food consumed by the household and on the efficiency of the household food budget. For WIC-type foods WIC families spend $2.54 more per week than do non-WIC women and each WIC child under five years of age accounts for an additional expenditure of $2.25 per week in WIC-type foods over non-WIC children. Moreover, WIC households spend $4.10 per week less on meals away from home than non-WIC households.

Diary data also show that each additional WIC child increases grocery expenditures by $5.82 per week. The significant positive impact of WIC children on food expenditures indicates that food purchased for children are not easily substituted for foods consumed by household adults. None of the equations for the diary data shows a significant interaction between household composition and WIC participation by women.

Conclusions

The results show that the WIC program mostly influences food composition rather than food expenditures. WIC program participants buy more WIC-type foods (presumably more nutritious) than do nonparticipants, even though no significant differences in total food expenditures were found between the WIC and non-WIC groups. The food expenditures recall data, although a cost-effective source of information, provide weak evidence of program impact. However, unchanged levels of food expenditures do not imply unchanged use of WIC-type foods. Rather, the restrictive nature of the WIC program seems to influence the nutrient composition of the market basket for the WIC family. That is, the income increase generated by WIC is tied to food instruments redeemable for specific foods and to the presence of an eligible pregnant woman in the household. A WIC household receives food coupons which are more difficult to exchange for cash than coupons from other nutritional assistance programs (e.g., food stamps).

Expenditures on WIC-type foods among WIC families are significantly greater than among non-WIC families. Although there is no direct evidence that such expenditures derive from program participation, the observation that expenditures in other food groups are the same for WIC and non-WIC families provides indirect evidence. Hence, the evidence suggests a positive program impact through increased use of

Table 4. Impact of WIC on Types of Food Purchased and on Types of Food Expenditures ($/Week)

Selected Independent Variables	Total Expenditures	Grocery Expenditures	Meals Away from Home	WIC-type Foods	Non-WIC Foods: Meats	Cereals and Bakery	Vegetables	Fresh Foods	Frozen Foods	All Foods
Intercept	62.15***[a]	52.13***	10.03***	8.46***	16.85***	8.92***	9.79***	25.32***	6.17***	33.23***
	(8.19)	(7.44)	(2.71)	(2.14)	(3.39)	(1.11)	(1.48)	(3.74)	(1.46)	(2.45)
Income	0.12**	0.11**	0.006	0.008	0.04**	0.009	0.02***	0.06***	0.002	0.10
	(0.04)	(0.03)	(0.004)	(0.01)	(0.01)	(0.005)	(0.007)	(0.01)	(0.006)	(0.03)
Male head present	−7.27**	−6.98***	−0.30	−1.66**	−1.96*	−1.60***	−1.18**	−2.78**	−0.84*	−5.56**
	(2.32)	(2.11)	(0.77)	(0.61)	(0.96)	(0.31)	(0.42)	(1.06)	(0.41)	(1.71)
Children 0–5	1.04	2.12	−1.08	1.07	0.03	0.51	−0.02	0.15	−0.18	2.93
years old	(2.46)	(2.23)	(0.81)	(0.64)	(1.02)	(0.33)	(0.44)	(1.12)	(0.44)	(3.09)
Adults	8.14***	7.10***	1.04***	1.14***	2.35***	1.23***	0.87***	3.66***	0.25	6.54***
	(1.20)	(1.10)	(0.39)	(0.32)	(0.50)	(0.16)	(0.21)	(0.55)	(0.21)	(0.94)
WIC	−3.34	0.75	−4.10***	2.54***	−1.25	−0.77	0.50	−1.24	−0.28	−0.93
	(3.02)	(2.75)	(0.99)	(0.79)	(1.25)	(0.41)	(0.54)	(1.38)	(0.54)	(2.38)
WIC*children	2.21	0.59	1.61	0.82	0.55	−0.38	−0.03	0.28	0.16	1.09
	(3.05)	(2.77)	(1.00)	(0.80)	(1.26)	(0.41)	(0.55)	(1.39)	(0.55)	(2.36)
WIC*adults	0.20	−0.06	0.27	0.44	−0.23	−0.06	−0.08	−0.71	0.27	−0.57
	(1.37)	(1.25)	(0.45)	(0.36)	(0.57)	(0.19)	(0.25)	(0.62)	(0.25)	(1.08)
Lunch program	0.29	0.37*	−0.08	0.03	0.10	0.04	0.03	0.14	0.04	0.26
	(0.21)	(0.19)	(0.07)	(0.05)	(0.08)	(0.03)	(0.04)	(0.09)	(0.38)	(0.26)
Guests	4.79**	3.47*	1.32*	0.33	0.73	0.80	0.48	1.38	0.15	2.12
	(1.75)	(1.59)	(0.58)	(0.46)	(0.72)	(0.24)	(0.32)	(0.80)	(0.31)	(1.39)
Food stamps	−0.13*	−0.04	−0.08***	−0.01	0.02	0.00	−0.03**	−0.03	−0.00	−0.00
	(0.06)	(0.05)	(0.02)	(0.01)	(0.02)	(0.008)	(0.01)	(0.03)	(0.01)	(0.04)
Other WIC Women	4.38	3.98	0.49	1.23	0.79	0.65	0.46	0.27	0.60	3.64
	(2.94)	(2.67)	(0.97)	(0.77)	(1.22)	(0.4)	(0.53)	(1.34)	(0.52)	(2.32)
WIC children 0–5	5.89*	5.82*	0.06	2.25**	0.29	0.95**	0.32	−0.05	0.81	−1.19
years old	(2.89)	(2.63)	(0.95)	(0.75)	(1.29)	(0.39)	(0.52)	(0.13)	(0.51)	(2.58)
Sample size	1582	1582	1582	1582	1582	1582	1582	1582	1582	1581
R^2	0.154	0.159	0.08	0.134	0.108	0.171	0.123	0.144	0.036	0.125
F	12.89	13.35	6.07	10.97	8.60	14.63	9.98	11.91	2.67	17.30

Source: Food Purchase Diary Sample.
[a]Triple asterisk indicates $p < 0.001$; double asterisk indicates $p < 0.01$; and single asterisk indicates $p < 0.05$.

nutritious WIC-type foods. Moreover, the impact of the WIC program on unintended recipients appears negligible.

Children's participation in the WIC program has significant and positive effects on both food expenditures and purchasing patterns. The evidence from both recall and diary data shows that children participating in the WIC program account for higher grocery expenditures than non-WIC children. The WIC program also exhibits a significant negative effect on expenditures for meals away from home. Unless WIC participation induces the purchase of expensive convenience foods, the results suggest that WIC increases the proportion of home cooked meals in the family diet.

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Testing for Structural Change: The Demand for Meat

Seungmook Choi and Kim Sosin

Recent research on meat demand demonstrates the importance in empirical demand analyses of identifying and measuring structural changes. This paper develops and applies a method of analyzing structural changes in preferences using parameters from empirical demand equations derived from an underlying utility function. Structural changes alter the marginal rate of substitution between goods at fixed points of prices and quantities. The evolution of preference changes is measured by time-varying multiplicative terms in a translog utility function. The application to meat concludes that structural change occurred in the 1970s and provides measures of the time pattern of demand shifts.

Key words: beef demand, meat demand, preference change, structural change, translog function.

A serious challenge in empirical demand analysis is the identification and understanding of structural change. Assessing and testing for structural change is particularly critical in studies of disaggregated consumer goods demand with time-series data. Because it may not be appropriate to assume a stable utility function with consumers' perfect knowledge of the good, researchers typically use statistical methods to identify points of structural inconsistencies over the sample period. While such empirical methods are often useful, structural change parameters should emerge from the theory if possible.

In this paper, preference changes in consumer demand for meat are studied using an extension of a well-known production theory of disembodied technical change (Solow). Structural changes in preferences are represented by time-varying multiplicative terms within an underlying utility function. A desirable feature of the empirical system of demand equations derived from the utility function is that parameters are directly available to measure and test for structural change.

For the empirical implementation of this type of model, prior knowledge about the pattern of the structural change in production or demand is very important. Diamond, McFadden, and Rodriguez showed, in the context of production theory, that it is not possible to identify the effects of changes in technology and in factor prices on the demand for inputs, given usual economic data, without such knowledge. While technological change in production theory may not evolve smoothly over time, preference transformations by consumers based on social change or on additional information about the quality of goods do appear to follow a diffusion process. For example, the marketing literature has many theoretical and empirical studies using the logistic pattern of the time-path diffusion process to describe the adoption of new products by consumers. (e.g., Bass, Olsen and Choi). This paper introduces, in the context of a translog utility function, time-dependent parameters following patterns appropriate to structural change arising from the diffusion of information. Although specification problems are always possible when an assumed structure is used to test directly for structural change (Haidacher), careful employment of a flexible functional form with embedded testable time path functions for parameter change which arise from an optimizing model appears to provide empirically useful results.

The analysis developed in this paper is applied to structural change in the demand for meat. Recent studies have argued that the structure of meat preferences shifted significantly in the 1970s, characterized primarily by a decline in the demand for beef and other red meat. While new information about fat and cholesterol in the

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diet appears to be a major explanation, other suggestions have ranged from the effect on expectations of unprecedented economic shocks in the 1970s (Braschler) to social and economic changes associated with the women's movement (Rausser, Mundlak, and Johnson).[1] According to one argument, the demand for convenience foods has increased, but at the same time concern for health has skewed preferences away from red meat. Beef, historically the basic convenience meat, was particularly hard hit by the consumer push towards more healthful eating. The new popularity of chicken in restaurants, and the introduction of franchise chicken fast food chains and restaurants further illustrates this point (Thurman).

Following the literature review, a new theoretical base for the empirical testing of structural change is presented. In the subsequent section an empirical translog model of multiplicative structural change is constructed using this theory. The data description and test results are provided in the next section, followed by the conclusions.

Literature Review

The observed demand changes stimulated researchers to develop and test statistical procedures to identify and measure structural change. Rausser, Mundlak, and Johnson provide a general specification that embeds as special cases all of the parameter variation models used in the literature to that date, among them Cooley and Prescott (1973a, b), Belsey, Swamy, Singh et al., Goldfeld and Quandt, and the spline regression models of Poirier and of Buss and Lim. Among the statistical approaches applied to the meat demand problem are a Kalman filter to handle parameter changes (Chavas), a switching regression specification in an inverse demand model (Braschler), a Box-Cox transformation to estimate alternative specifications of demand (Moschini and Meilke), and a "least absolute value" technique to identify data shifts from outliers associated with structural change (Yanagida and Book). Other economists have studied the time patterns of consumer demand for meat (e.g., Wohlgenant and Hahn). The general, although not conclusive or unanimous, result of these studies is that a structural shift occurred in U.S. red meat preferences in the mid-1970s.[2]

Other researchers have emphasized the role of relative prices in the meat decline. Wohlgenant uses a seminonparametric method specifying a Fourier flexible functional form. Although his major conclusion is that mid-1970s shifts in demand for beef stem from changes in relative prices of beef and poultry rather than preference changes, he also finds that beef demand became more sensitive to poultry prices and that the relationship between beef and fish changed from substitutability to complementarity. Also, Martin and Porter identify relative price changes as the major cause of consumer demand changes in Australia but detect some structural change.

A different approach, based on a nonparametric test for structural change, was used by Chalfant and Alston. Their meat consumption data appear to satisfy the strong axiom of revealed preference. Although the power of such tests is uncertain, their work suggests that the data are consistent with utility maximization and therefore a stable utility function. The parametric approaches cannot rule out the possibility of a false rejection of the null of stability because of model misspecification; however, the wide variety of approaches and flexible form specifications finding structural change suggest that at least this question is open to further study.

Multiplicative Structural Change in Consumer Demand Theory

Hypothesis tests for structural change in consumer demand have not typically been based upon parameters derived from the utility maximization principle. Most studies have proceeded by direct parameterization of theoretical variables such as price elasticities and income elasticities, followed by examination of the stability of those parameters. However, differences in price and income elasticities do not necessarily imply structural change. It is unlikely that these parameters, even from a given preference structure, would be consistent across two time pe-

[1] For example, a midwestern newspaper recently referred to "a yuppie aversion to red meat" (*Omaha World Herald*, "For First Time, Poultry Takes Lead Over Beef," 3 Jan. 1988). Also Chalfant and Alston report that it is "widely suggested in industry circles that this reflects a shift in consumer preferences due to dietary concerns" and has been the impetus for developing new grading systems for beef (p. 395).

[2] One study whose empirical finding is contrary to structural change (Moschini and Meilke) uses the Box-Cox transformation. Although this parametric approach has the advantage of using a flexible specification, this flexibility also raises some questions. First, no criteria are presented for deciding which of the parameters are to be shifted. Second, flexibility may result in a high degree of fit at the expense of theoretical regularity conditions, which cannot be checked.

riods if other economic variables vary; that is, if the price ratios or the income levels between the two periods are different, the elasticities are likely to be different with or without a structural shift. An appropriate comparison of elasticities must be done at a fixed data point of prices and income levels, which is almost impossible with the usual model specification in the literature.

Suppose that the source of structural change in demand is a change in information held by consumers about the characteristics or attributes of goods. As consumers' information about goods' attributes changes, the resulting rearrangement of preferences generates a shift in the marginal rates of substitution at given points in the consumption space.

This type of structural change can be described conveniently by extending the framework of the specification of disembodied technical change in growth models. Let $x = (x_1, x_2, \ldots, x_n)$ be the quantity vector of goods in nonnegative orthant n-dimensional Euclidean space x, and let $q(t) = (q_1(t), q_2(t), \ldots, q_n(t))$ be the vector such that $q_i(t) = a_i(t)x_i$ for all i, where the $a_i(t)$ are nonnegative functions of time.[3] Call q_i the information-augmented quantity (IAQ) of good x_i. A natural interpretation is that, given fixed actual quantities of x_i, consumers' perceived IAQ or q_i changes by time-dependent scaling parameters. For red meat consumption, for example, as consumers realize the potential danger of cholesterol, a pound of red meat takes on a different implied weight of red meat consumption, so that $a_i(t)$ [and thus $q_i(t)$] change for given x_i. Conversely, if the consumers' decision is based on q rather than observed market goods x, consuming the same amount of q_i over time necessarily implies a change in market purchases of x_i with the time-varying parameter $a_i(t)$.

We assume that a representative consumer has a stable preference structure over the information augmented goods; that is, the preference defined over the IAQ space Q is time-invariant. However, preferences for the actual quantity of goods X may be changing over time. Therefore the consumer's utility function u_t at time t, defined on X, may be written as

$$u = u_t(x) = U(q_t),$$

where

$$(1) \quad q_t = (a_1(t)x_{1t}, a_2(t)x_{2t}, \ldots, a_n(t)x_{nt}).$$

The functional form of $a_i(t)$ characterizes how the change in technology or preference is processed on good x_i. We define a preference change as multiplicative if a vector $(a_1(t), a_2(t), \ldots, a_n(t))$ of functions exists that satisfies (1) such that $a_i(t) > 0$ for all i and t. It is not difficult to show that if a preference change is multiplicative, and if one of u_t or U satisfies the standard regularity conditions such as quasi-concavity and monotonicity in its own argument space, then the other will do so also for a given t.[4] Note that equation (1) is identical to the disembodied technological change specification in production theory.

An empirical model for testing the hypothesis of structural change should permit a comparison of theoretical parameters at a given data point. However, in some cases a change in preference may affect demand yet not alter the values of elasticities at a single data point. An example can be drawn from a CES utility function, in which the elasticities of substitution are constant for all data points even if the values of other parameters are changed. However, in general, a change in demand from any preference change should affect the marginal rate of substitution (MRS) at a data point.[5] Indeed, if a structural change is multiplicative, the MRS between goods in X is never constant as t changes except for a

[3] The transformation of x into q may be viewed as similar to the transformation of market goods into "characteristics" or "attributes" of Becker and Lancaster, to the extent that preferences defined on the consumption characteristics (IAQ) are stable, and structural change need not imply changes in preferences for the transformed consumption characteristics from market goods. However, the transformed variables, q_i, from using the multiplicative terms do not generate the unique characteristics in the Becker and Lancaster sense.

[4] If a preference change is multiplicative, then the regularity conditions of u_t on x are preserved in its transformed space Q and vice versa. It is trivial to show the preservation of monotonicity. Proof of the preservation of quasi-concavity: Let u_t be quasi-concave. Then, for two distinct bundles, x^0 and x^1 such that $u_t(x^0) > u_t(x^1)$, and for a real number λ such that $0 < \lambda < 1$,

$$u_t(\lambda x^0 + (1-\lambda)x^1) > u_t(x^1).$$

Let $q^0 = A_t \cdot x^0$ and $q^1 = A_t \cdot x^1$. Then, $u_t(x^0) > u_t(x^1)$ implies $U(q^0) > U(q^1)$ by definition. And

$$\begin{aligned} u_t[\lambda x^0 + (1-\lambda)x^1] &= U[\lambda A_t x^0 + (1-\lambda)A_t x^1] \\ &= U[\lambda q^0 + (1-\lambda)q^1] \\ &> u_t(x^1), \\ &= U(q^1). \end{aligned}$$

Thus,

$$U[\lambda q^0 + (1-\lambda)q^1] > U(q^1).$$

The converse can be proved easily by a similar method.

[5] For a two-commodity CES production function

$$U = A(\delta x_1^{-\rho}) + (1-\delta)x_2^{-\rho})^{-1/\rho},$$

the elasticity of substitution between x_1 and x_2 is $1/(1+\rho)$. Therefore, a change in the value of δ will not alter the elasticity but will alter the value of the marginal rate of substitution at a given data point. Of course, a monotonic transformation of the utility function is not considered a type of preference change.

special case that is negligible in empirical demand analysis. Of course, with fixed preferences, the MRS also changes with an altered price ratio. To avoid the identification problems raised by Diamond, McFadden, and Rodriguez, the empirical specification must be able to separate the effects on MRS of price changes from preference changes. To do so, the multiplicative model in our specification imposes a flexible and reasonable pattern of evolving or declining preferences with eventual upper or lower limits on $a_i(t)$.

The magnitude and direction of the change in MRS between goods in X over time can be examined from the first partial derivative of the MRS with respect to time t, or equivalently, with respect to a_j.

Let the MRS between q_j and q_i be written

$$-(\partial q_i/\partial q_j) = (MU_{q_j}/MU_{q_i}) = f(q_1, q_2, \ldots, q_n),$$

where MU denotes marginal utility. But for any given t,

$$-(\partial q_i/\partial q_j) = -\frac{a_i}{a_j}\frac{\partial x_i}{\partial x_j}.$$

Thus,

$$(2) \quad -(\partial x_i/\partial x_j) = (a_j/a_i)f(q_1, q_2, \ldots, q_n).$$

Taking the partial derivative of (2) with respect to a_j to identify changes in MRS over time, we obtain

$$(3) \quad \frac{\partial[(a_j/a_i)f(q_1, q_2, \ldots, q_n)]}{\partial a_j} = (1/a_i)f(q_1, q_2, \ldots, q_n) + \frac{a_j}{a_i}\frac{\partial f(q_1, q_2, \ldots, q_n)}{\partial a_j}$$
$$= (1/a_i)f(q_1, q_2, \ldots, q_n) + \frac{q_j}{a_i}\frac{\partial f(q_1, q_2, \ldots, q_n)}{\partial q_j}.$$

Further implications of (3) for structural change can be easily described. A nonzero value for equation (3) indicates a change in the MRS between good x_j and x_i at one data point in consumption space X, therefore a structural shift in demand. The value of (3) can be positive, negative, or zero, depending on the elasticity of substitution and other features of the utility function.

For illustration, consider a constant elasticity of substitution (CES) form of the utility function, where x_i and x_j are the two goods. Given the value of the elasticity of substitution, the demand for x_j is shown to be decreasing or increasing by the value of $a_j(t)$. If the elasticity of substitution is less than (greater than) one, then the value of equation (3) is negative (positive).[6] When equation (3) is negative (positive), the demand for x_j is decreased (increased) as $a_j(t)$ increases over t, given fixed income and prices. The MRS between i and j would also change with a new a_k, for $k \neq i, j$, unless goods i and j are block-wise separable from the bundle of goods containing the kth good. Given separability, equation (2) is independent from q_k, and so is a_k, by definition of separability (Blackorby, Primont, and Russell).

A potential problem in measuring structural change is created for the empirical model if the value of (3) is zero. The Cobb-Douglas utility function is the only case for which the value of equation (3) is zero under multiplicative structural shift for any given positive real number a_i.[7] Because a Cobb-Douglas utility function is unlikely, this is not a serious problem for our test. If the utility function is Cobb-Douglas, then multiplicative structural change is merely a form of monotonic transformation and will not be identified as structural change. This is the analog in demand theory of the well-known growth theory result that if a production function is of Cobb-Douglas form, then disembodied technical progress does not affect the ratio of factor combinations.

The Empirical Translog Model

Empirical demand systems are usually derived from indirect utility specifications. Many existing flexible functional forms could be transformed into empirical models incorporating multiplicative structural change. We have cho-

[6] Let the CES function be

$$U = A(\delta q_1^{-\rho} + (1-\delta)q_2^{-\rho})^{-1/\rho};$$

where $q_1 = a_1x_1$ and $q_2 = a_2x_2$. Then,

$$f(q_1, q_2) = \left(\frac{\delta}{1-\delta}\right)\left(\frac{q_2}{q_1}\right)^{(1+\rho)}.$$

If $\rho > 0$, then $\sigma < 1$ and equation (3) > 0. If $-1 < \rho < 0$, then $\sigma > 1$, and equation (3) <0.

[7] An appendix showing that the Cobb-Douglas utility function is the only case for which the value of equation (3) is zero under multiplicative structural shift for any given positive real number a_i is available from the authors upon request.

sen the translog specification for its simplicity and popularity. A convenient feature of multiplicative structural change is that the functional structure is preserved from the direct utility function to the indirect utility function.

Consider the following utility maximization problem for time t:

$$(4) \qquad \text{Max } U_t(x_{1t}, x_{2t}, \ldots, x_{nt}), \quad \text{subject to } \sum_i p_{it}x_{it} = m_t,$$

where p_{it} is the price of good i at time t, and m_t is total expenditure at time t. If the preference change is multiplicative, then the maximization of (4) is mathematically equivalent to the following problem:

$$(5) \qquad \text{Max } U(q_{1t}, q_{2t}, \ldots, q_{nt}), \quad \text{subject to } \sum_i z_{it}q_{it} = m_t,$$

where $z_{it} = p_{it}/a_i(t)$ and $q_{it} = a_i(t)x_{it}$. The subscript t of U in (5) is deleted because the utility function is assumed to be stable on IAQ space. Following Christensen, Jorgenson, and Lau, the indirect utility function dual to the utility function (5) is of the form

$$V = v(z_{1t}/m_t, z_{2t}/m_t, \ldots, z_{nt}/m_t) = V(b_1(t)p'_{1t}, b_2(t)p'_{2t}, \ldots, b_n(t)p'_{nt}),$$

where $b_i(t) = 1/a_i(t)$ and $p'_{it} = p_{it}/m_t$. In terms of the model employed for this study, the translog specification of the indirect utility function defined over the transformed z_i vector space is

$$(6) \quad \text{Log } V = c_O + \sum_i c_i(\log(z_i/m) + (1/2)\sum_i\sum_j c_{ij}(\log(z_i/m)(\log(z_j/m)),$$

where time subscript t is omitted for notational simplicity. Applying modified Roy's identity, the following share equations are obtained:

$$(7) \quad \frac{z_iq_i}{m} = \frac{c_i + \sum_j c_{ij}(\log(z_j/m))}{\sum_k c_k + \sum_k\sum_j c_{kj}(\log(z_j/m))},$$

for all i, or

$$(8) \quad \omega_i = \frac{p_ix_i}{m} = \frac{c_i^* + \sum_j c_{ij}(\log(p_j/m))}{\sum_k c_k^* + \sum_k\sum_j c_{kj}(\log(p_j/m))},$$

for all i.

where $c_i^* = c_i + \Sigma_j c_{ij}\log(b_j(t))$. The value share equations (8) are identical to those derived from the usual translog indirect utility function if $b_j(t) = 1$ for all j and t. With the appropriate specification of $b_j(t)$, the testing of structural change in the translog equation (8) is equivalent to checking the statistical consistency of the first-order terms, c_i^*, over the sample period.

The next step in the empirical specification of the multiplicative preference change model is to choose a $b_j(t)$ function that facilitates an appropriate pattern of structural change. While many specifications are possible, we introduce two convenient one-parameter relationships, the step function and the smooth logistic function.

Step Function

Often a structural shift is assumed to occur at a particular time when new information becomes available and preferences change. Hence the sample is divided into before and after subsets, with estimation applied to each sample period and to the whole period. The null hypothesis of equality of coefficients across the subperiods is accepted or rejected by a comparison of the sums of the squared residuals. In contrast, for the multiplicative structural change case, a preference shift with this before and after pattern can be specified within the model by choosing a step function for $b_j(t)$.

$$b_i(t) = 1 \text{ if } t < t_0$$
$$b_i(t) = \exp(\beta_i) \text{ if } t \geq t_0,$$

where t_0 is the date when the structural change is believed to have begun. If $\beta_i = 0$, then $b_i(t) = 1$ for all i, and the share equations are those of the simple translog function. Thus, a test of the null hypotheses $\beta_i = 0$ is equivalent to a test of no structural change for good i; if β_i is significantly different than 0, the null hypothesis of no structural change is rejected. The direction of the shift is shown by the sign of β_i. If β_i is less than (more than) 0, then $b_i(t)$ is a decreasing (increasing) function of t.

Smooth Function

Rather than a sudden step of the preference structure at a given time, preferences may exhibit a smooth evolution throughout the sample period. In this case, $b_i(t)$ should be specified as continuous in t and have an arbitrary upper and lower limit as $t \rightarrow \infty$. In addition, to maintain degrees of freedom, it is desirable (although not necessary) to again choose a function for $b_i(t)$ with only one parameter. For these reasons, the logistic function is an ideal choice:

$$b_i(t) = 1/(1 + \exp(\beta_i t)).$$

In this function, if $\beta_i = 0$, then $b_i(t) = 1/2$ for all t and i. Thus, equation (8) does not collapse to the original translog share equations when $\beta_i = 0$. However, because of the nature of the value share equations, for statistical inference purposes a constant $b_i(t)$ will make equation (8) equivalent to the original equations. When $\beta_i = 0$ is imposed and $b_i(t)$ is unvarying, the constants c_1 and c_2 can be arbitrarily determined by the fixed values of the second-order terms of the translog specification. Therefore, like the case of the step function, if β_i is significantly different from zero, the null hypothesis of structural change will be rejected. In fact, there will be no difference in any statistical result—for example the sum of squared residuals or t-ratios of parameter estimates—between the original translog equation and equation (8) with $\beta_i = 0$ imposed. Note that if β_i is greater than (less than) zero then $b_i(t)$ is a decreasing (increasing) function of time t.

The use of the logistic function to study structural change in consumer demand is most appropriate when new or revised information is the major source of structural change. The theoretical discussion of and empirical application of the logistic function can be found in the literature on new product growth based on time-diffused information (Bass, Olsen and Choi).

Data and Estimation

The above variations of the translog model were applied to the demand for food in the United States, using three food items, red meat, poultry, and other foods (hereafter denoted by subscripts 1, 2, and 3), such that total expenditure on these items is equal to total consumption of food. The choice of these three goods can be rationalized by the usual assumption of separability of preferences; that is, assume that these three goods are separable from other goods in consumers' preferences. Beef was not separated from other red meat because, first, consumer health concerns may apply to the entire red meat category and, second, a consequence of adding another good is a large loss of degrees of freedom from additional parameters associated with the translog and the structural change functions. Annual time-series per-capita indexes from 1953 through 1984 covering retail quantities for red meat, poultry, and other food ("all food" less red meat and poultry) were obtained from *Food Consumption, Prices, and Expenditure*, and *U.S. Food Consumption Sources of Data and Trends* (USDA).[8]

The full information maximum likelihood estimation technique was applied to equation (8) for estimation of the parameters, with additive disturbance terms assumed contemporaneously correlated.[9] With the additive disturbance specification, it is well-known that the contemporaneous variance-covariance matrix of disturbances does not possess full rank. Barton and Theil (1976, 1971) showed that the rank is the number of goods in the system of demand equations less one. The maximum likelihood estimates are invariant to the equation deleted, which was the demand equation for other foods in this study. The usual normalization for identification of the models and the symmetry are imposed by setting $\Sigma_i c_i = -1$ and $c_{ij} = c_{ji}$ for all i and j, respectively. The starting values for coefficients were obtained from nonlinear OLS estimates of the system.

Equation (8) with additive disturbance terms was estimated several times: first, for no structural change [$b_i(t) = 1$ for all i]; second, for the step function; and, third, for the logistic function. To illustrate the step function we assume that information change affects red meat only, that is, for red meat, $b_1(t) = \exp(\beta)$ but $b_i(t) = 1$ for $i = 2, 3$. Based on previous work suggesting that structural change began in the mid-1970s, $t_0 = 1974$ is assumed to be the critical time period of the shift of preference structure (e.g., Braschler). The step data cannot be tested directly, but if the step function was deemed appropriate for structural change in a particular application, it could be estimated with each pos-

[8] Expenditures in 1967 for each item were used, with the retail weight quantity indexes based at 1967, to construct constant 1967 dollar values of quantity of retail meat. Price indexes were also normalized to 1967. We thank Howard Elitzok of the USDA for providing the data.

[9] The GRG2 Fortran nonlinear programming package developed by Leon Lasdon at the University of Texas at Austin was used.

sible date as the step date, and the likelihood values compared.

For the logistic function, three cases are analyzed, each implying a different impact of information change on food demand. Although it is believed that the information change had its primary impact on red meat demand, this assumption is imposed on only the first case. Accordingly, for the first logistic function case, $b_2(t)$ and $b_3(t)$ are set equal to 1, for the second case, only $b_3(t)$ is set equal to 1, and finally, no $b_i(t)$ coefficient is assumed to be 1 so that all are determined by the estimation. For all cases, the form $b_i(t) = 1/(1 + \exp(\beta_i(t - t^*))$ is used, where t^* is the middle data point. The purpose of introducing t^* is to minimize possible rounding errors in the computation.

Both the t-test and likelihood ratio test procedure were executed on the hypotheses.[10] It is well known that twice the difference of the log-likelihood values between unrestricted and restricted parameter spaces ($2 \log \lambda$) is asymptotically chi-square distributed with q degrees of freedom, where q is the number of restrictions imposed on the parameter space.

[10] The asymtotic standard errors for the t-statistics were obtained by inverting the information matrix evaluated at the parameter estimates. This requires that the second-order derivatives of the log-likelihood function be computed numerically (e.g., $\Delta \log L(c))/\Delta c^2$, where Δ is the difference operator and c is a parameter value), in which case the value of the second-order derivatives may be very sensitive to the choice of Δc. In our estimation, we have used $\Delta c = c^* \cdot 0.00025$, where c^* is the maximum likelihood estimate. Our experience was that 0.00025 is small enough relative to the parameter estimates for the numerical derivatives. Also, we tried other small values with no significant change in computed t-values. However, in the likelihood ratio test, this problem can be avoided.

Empirical Results

Tables 1 and 2, and figure 1 present the results of the estimation. Table 1 displays the parameter estimates for the three cases—no structural change (model 1), abrupt structural change (step function model labelled 2-1), and evolutionary structural change (logistic function models 2-2, 2-3, 2-4). For the logistic function, the three versions described earlier are shown: $i = 1$, $i = 1, 2$, and $i = 1, 2, 3$ for models labelled 2-2, 2-3, and 2-4, respectively. The percent violation row in table 1 indicates the percent of the data points that violate theoretical conditions. At each data point, monotonicity was checked by evaluating the sign of the predicted value share, where a negative value implies violation, and the quasi-convexity requirement on V was checked by examining if the estimated matrix of the elasticities of substitution is negative semidefinite (Caves and Christensen). Also indicated for each func-

Table 1. Maximum Likelihood Estimates of Structural Change Models

		Model 2: Multiplicative Change			
	Model 1	$b_1(t) = \exp(\beta_1)$	$b_i = 1/1 + \exp(\beta_i t)$		
Parameters	No Change	(2-1)	(2-2) $i = 1$	(2-3) $i = 1, 2$	(2-4) $i = 1, 2, 3$
c_1	0.089 (1.86)[a]	0.354 (4.03)	0.090 (5.02)	−21.86 (−3.68)	0.020 (0.36)
c_2	0.025 (1.09)	0.063 (2.71)	0.002 (0.33)	−3.083 (−3.36)	0.004 (0.23)
c_{11}	−.023 (−2.05)	0.008 (0.67)	0.006 (5.49)	0.903 (1.47)	−0.010 (−0.37)
c_{12}	0.001 (0.57)	0.006 (4.51)	0.002 (7.22)	−0.152 (−1.74)	0.001 (1.26)
c_{13}	0.060 (5.38)	0.087 (4.67)	−.024 (−7.09)	−6.317 (−5.02)	0.024 (1.08)
c_{22}	−.001 (−2.90)	−.002 (−3.78)	−.001 (−5.10)	0.411 (4.25)	−.003 (−1.04)
c_{23}	0.009 (1.85)	0.013 (2.76)	0.002 (1.26)	−1.036 (−5.43)	0.005 (1.39)
c_{33}	−.272 (17.50)	−.361 (10.38)	−.240 (−34.74)	8.656 (4.18)	−.198 (−58.17)
β_1		−.461 (−1.99)	0.720 (3.85)	0.126 (10.56)	0.148 (1.12)
β_2				0.032 (3.63)	0.016 (0.67)
β_3					0.020 (0.62)
Value of log-likelihood	367.069	374.747	388.633	392.362	398.99
% Violation[b]	100%	25	3.1	9.4	12.5
Beef consumption % Change[c]		−8	−13.5	−11.2	−13.1

[a] Asymptotic t-ratios are in parentheses.
[b] Percent of data points that violate regularity conditions.
[c] Given fixed 1974 income and prices, percent decrease in per-capita beef consumption over the period of 1970 and 1984.

Table 2. Estimated Price and Income Elasticities

	Model 1	Model 2 (2-1)	Model 2 (2-2)	Model 2 (2-3)	Model 2 (2-4)	Model 3
π_{11}[a]	−0.579	−0.836	−0.971	−0.672	−0.756	−0.452
π_{12}	0.018	−0.013	−0.013	0.007	−0.004	0.032
π_{13}	−1.458	−1.416	−1.105	−0.924	−1.215	−1.000
π_{21}	0.066	−0.066	−0.010	0.084	−0.022	−0.080
π_{22}	−0.907	−0.871	−0.893	−0.648	−0.639	−0.763
π_{23}	−1.333	−1.307	−0.937	−0.863	−1.322	−1.574
π_{31}	−0.169	−0.057	−0.010	−0.131	−0.091	−0.210
π_{32}	−0.013	−0.004	−0.002	−0.027	−0.023	−0.028
π_{33}	−0.340	−0.385	−0.523	−0.589	−0.447	−0.501
η_1[b]	2.019	2.265	2.090	1.588	1.975	1.420
η_2	2.174	2.244	1.841	1.427	1.983	2.416
η_3	0.523	0.445	0.536	0.747	0.562	0.740

[a] π_{ij} is Marshallian cross-price elasticity of demand for good i with respect to good j.
[b] η_i is income elasticity of demand for good i.

tion are the value of the log likelihood function, and the implied percent change from 1970 to 1984 in per capita red meat consumption, given fixed 1974 income and prices.

By all standards, the multiplicative change logistic function of model 2 is preferred, further, the results of the t-test procedure and percent violation test indicate that models 2-2 and 2-3 provide an excellent fit with few points of violation. The t-test and loglikelihood ratio statistics for the null hypothesis that $\beta_1 = 0$ support the occurrence of structural change in red meat consumption. The estimated decline in per capita red meat consumption is similar, −13.5% in model 2-2 and −11.2% in model 2-3.

An alternative model was also estimated to test for structural change (Diewert and Wales; Ewis and Fisher). This model uses a flexible functional form and time t as a function argument for technological change. In this model time is usually used as an explicit argument in the expression for technological change when the true technological index is unknown and a change in technology is suspected. It appears to be general, but with a translog function it is equivalent to a particular multiplicative structural change specification that may be unduly restrictive.[11] A test of this approach yields inferior results for the log-likelihood value and for coefficient significance compared to multiplicative structural change, and over 95% of the data points violate regularity conditions.

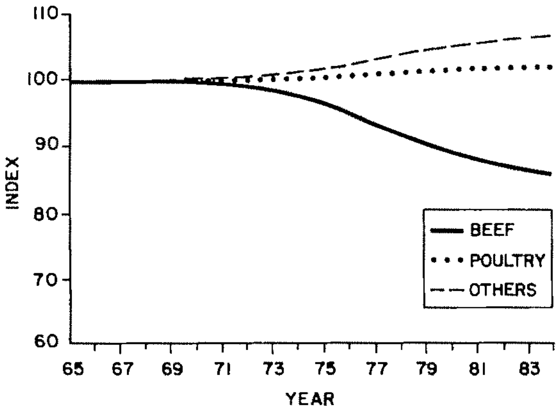

Figure 1. Predicted consumption quantity indexes

The logistic function model 2-2 was used to generate predicted annual consumption quantity indexes, normalized at 1965 = 100, for given income and prices fixed at 1974 levels. The plotted indexes, shown in figure 1, are a dramatic illustration of the impact of structural change on red meat demand. If consumers be-

[11] Given the unknown true indirect utility function whose argument includes time T, $V = V(p'_1, p'_2, \ldots, p'_m, T)$, the second-order Taylor series approximation in logarithms yields

$$\begin{aligned} \text{Log } v = a_0 &+ \textstyle\sum_i a_i(\log(p_i/m) \\ &+ (1/2) \textstyle\sum_i \sum_j a_{ij}(\log(p_i/m)(\log(p_j/m)) + a_T \log T \\ &+ 1/2 \textstyle\sum_i a_{iT}(\log(p_i/m))(\log T) + 1/2\, a_T(\log T)^2. \end{aligned}$$

Applying Roy's identity:

$$\omega_i = \frac{a_i^* + \sum_i a_{ij}(\log(p_j/m))}{\sum_k a_k^* + \sum_k \sum_j a_{kj}(\log(p_j/m))} \text{ for all } i,$$

where $a_i^* = a_i + a_{iT} \log T$ for all i. Hypothesis testing for structural change is the same as testing if a_{iT} is significantly different from zero for all i. This is equivalent to the multiplicative structural change specification of power function $b_j(t) = T^{a}jT$. A restriction is that the process converges only if a_{jT} is less than zero.

came cognizant of the impact of fat and cholesterol on health over the period from 1970 to 1984, these and other concerns appear to have caused the per capita red meat consumption index to drop by over 10% for given prices and incomes. Earlier studies had suggested, and the logistics model confirms (fig. 1), that the decline in red meat consumption was activated at about 1974, a timing result that was not imposed on this model.

Table 2 provides estimates of the elasticity parameters from each equation for red meat, poultry, and other foods. The elasticities represent an average over the data points for the sample time period. The π_{ij} are Marshallian cross-price elasticities of demand for good i with respect to j, and the η_i are income elasticities for good i. All elasticities look reasonable in sign, even for those models with violation of utility maximization conditions for 95%–100% of the data points. Clearly a set of appropriate signs for the elasticities is not enough evidence to conclude that the model is appropriate.

A word of caution is in order. As stated earlier, based on their nonparametric results, Chalfant and Alston do not reject the existence of a stable utility function. If their conclusion is correct, our results may imply inflexibility of the translog function. However, we found that introducing one multiplicative term on meat only satisfies the regularity conditions at all data points but one. The monotonically decreasing scaling parameter $b_1(t)$ causes the indifference curve of the translog utility function defined on consumption space x to rotate in one direction constantly over the sample period. A substantial improvement of the regularity conditions by such rotation of the indifference curves over the thirty-two-year time span suggests that a smooth preference change has occurred.

Conclusions

This paper introduces a method with roots in technological change theory for identifying, measuring, and testing for structural change in the preferences of consumers. The method proves useful in identifying structural change in red meat demand in the mid-1970s in the United States. Structural change is specified as a time-varying multiplicative term within an underlying consumer utility function. The translog flexible functional form specification for the underlying utility function is used to develop the equations for estimation, which incorporate first a step function, and then a smooth logistic function as the multiplicative term.

Although any parametric approach is subject to misspecification, multiplicative structural change offers several advantages. First, empirical tests are directly based on parameters derived from microeconomic theory, unlike the usual procedure of relying on purely statistical approaches. Second, a wide variety of patterns of structural change can be measured, based on a judicious choice of functional form for the multiplicative term.

In the application to meat demand, the empirical model with multiplicative structural change produced improved statistics of fit compared to the case of no structural change, and to the alternative approach used by Diewert and Wales and by Ewis and Fisher. Although all estimations yield reasonable signs for all prices and income elasticities, the assumptions of monotonicity and quasi-convexity are violated in over 95% of the data points in the models of no structural change and the alternative approach. These problems are not present in the logistic function models. Estimations of the logistic function models support the existence of structural decline in U.S. red meat demand since the early 1970s.

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Comment and Reply

An Inverse Demand System for U.S. Composite Foods: A Comment

Trevor Young

In a recent article in this *Journal*, Huang summarized the theoretical basis of inverse demand systems and estimated a set of price flexibilities for U.S. aggregate food groups. Following Anderson, attention focused on the theoretical constraints on compensated and uncompensated flexibilities. These constraints are analogous to the familiar "general restrictions" of standard demand theory—homogeneity, Cournot aggregation, Engel aggregation, and Slutsky relations. However, Huang neglected to record another aspect of the dual nature of inverse and quantity-dependent demand systems, the property, demonstrated by a number of authors including Anderson and Houck, that the matrix of price elasticities can be derived by inverting the matrix of flexibilities. This duality is important to note because it provides a link between inverse and "direct" demand systems and so allows all the elasticities and flexibilities to be computed, given the values of budget shares, once either set of parameter values has been estimated. Moreover, the derivation of elasticities provides an additional check on whether estimates obtained from an inverse demand system accord with a priori reasoning. It is the purpose of this note to demonstrate that when this additional computation is performed on Huang's model, the validity of his results is brought into question.

Huang presented the set of estimated compensated flexibilities (f_{ij}^*) for thirteen food products and a nonfood aggregate, together with their respective budget weights (w_i), and the scale flexibilities (g_i). (A hint that something may be amiss in the model is given by the positive, albeit statistically insignificant, own-quantity compensated flexibility for fish.) From this information, the uncompensated flexibilities (f_{ij}) are obtained as follows:

$$f_{ij} = f_{ij}^* + g_i w_j.$$

Assuming the matrix of these flexibilities ($F = \{f_{ij}\}$) is invertible, then the matrix of price elasticities ($E = \{e_{ij}\}$) is computed as

$$E = F^{-1}.$$

Using the homogeneity condition, income elasticities (η_i) are given by

$$\eta_i = -\sum_j e_{ij}.$$

Finally, the compensated elasticities (e_{ij}^*) can be retrieved from

$$e_{ij}^* = e_{ij} + \eta_i w_j.$$

These computations, when based on the econometric estimates of compensated flexibilities reported by Huang, provide the elasticity estimates recorded in table 1; to save space only own-price and income elasticities are presented. The unacceptable nature of these results is immediately clear. Five of the compensated price elasticities (fish, dairy, fats, fruits, non-food) violate the "law of demand," given that a fundamental property of the (negative semidefinite) Slutsky matrix is that its diagonal elements must be nonpositive. These perverse results carry over, in four cases, to the uncompensated forms of the own-price elasticities. It would therefore be concluded that either the bias in aggregation has been so great that the theoretical restrictions do not hold at the market level, or the constraints are indeed valid but the model has been misspecified in some way. In any event, if these additional computations had been undertaken, it is doubtful whether the researcher would have been as satisfied with the analysis.

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Table 1. Own-Price and Income Elasticities Derived from Huang's Model

	Compensated Price Elasticity	Uncompensated Price Elasticity	Income Elasticity
Beef V	−1.032	−1.043	0.352
Pork	−0.854	−0.866	0.507
Poultry	−1.313	−1.319	0.659
Fish	2.124	2.114	2.616
Eggs	−0.196	−0.200	0.358
Dairy	0.645	0.637	0.210
Fats	1.316	1.309	0.948
Fruits	2.649	2.649	−0.004
Vegetables	−0.421	−0.425	0.313
Pro. Fv.	−0.703	−0.716	0.629
Cereal	−0.045	−0.029	−0.898
Sugar	−0.294	−0.296	0.072
Beverages	−0.711	−0.716	0.910
Nonfood	0.330	−0.606	1.173

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An Inverse Demand System for U.S. Composite Foods: Reply

Kuo S. Huang

In his comment, Young attempted to verify Huang's empirical inverse demand system by first deriving an uncompensated price flexibility matrix from Huang's compensated price flexibility estimates and then inverting the derived uncompensated price flexibility matrix to obtain what he claimed to be a demand elasticity matrix. The approach he uses for verification, however, is conceptually and empirically inadequate.

First, Hicks has systematically treated the inverse demand and defined "q-complements" and "q-substitutes" of the Antonelli matrix in contrast to the "p-complements" and "p-substitutes" of the well-known Slutsky matrix in ordinary demand. As shown in Deaton and Muellbauer (p. 57), the Antonelli matrix and Slutsky matrix are closely linked; they are generalized inverses of each other. Conceptually, if one intends to verify the dual nature of a demand system, one should focus on the generalized inverse relationships between the Antonelli and Slutsky matrices rather than using Young's intuitive approach by comparing the estimated price flexibilities with the derived demand elasticities. Moreover, Young's demand elasticity matrix is derived from a constructed uncompensated price flexibility matrix that departs from the functional form specified in Huang's inverse demand system. I know of no theoretical basis to verify the inverse demand system by using Young's derived demand elasticity matrix that is obviously outside the framework of the initial model specification for the inverse demand system.

Second, in general, the empirical demand elasticity and price flexibility matrices obtained from certain well-known estimation procedures are not the reciprocal of one another in a statistical sense because the two sets of regression lines differ from one another. In an ordinary demand system, the sum of residuals is minimized along the quantity axis; whereas, the sum of residuals is minimized along the price axis in an inverse demand system. The problem was discussed in Houck, who summarized some earlier studies and concluded: (a) the reciprocal of the direct price flexibility is not in general the same as the direct price elasticity, and (b) the reciprocal of the price flexibility is absolutely less than the true elasticity if there are discernible cross effects with other commodities. Thus, Young's demand elasticity matrix, which is computed as the reciprocal of a derived uncompensated price flexibility matrix, has limited practical use because the elasticity matrix may not represent the "true" demand structure as reflected from the sample observations. Perhaps a statement from Waugh (pp. 29–30) best addresses this point: "I prefer to use the price flexibilities themselves rather than their reciprocals. If, for any reason, the elasticity of demand is wanted, I would prefer to use the other regression equations, using quantities as the dependent variables."

Third, there are at least two additional drawbacks in Young's effort to obtain a matrix of demand elasticities by inverting a derived uncompensated price flexibility matrix. One drawback relates to ignoring the stochastic properties of point estimates for Huang's compensated price flexibilities, which are subject to certain probability distributions with means and variances. In his inversion process, Young treats the point estimates as pure numbers representing the true parameters but ignores the associated variance. It becomes apparent that Young only partially considers the stochastic nature of Huang's estimates. Another drawback is that the inverted results are quite sensitive to the numerical structure of the matrix being inverted. We should be aware that the potential problem of singularity or near singularity in such a big matrix (14 x 14 in our case) is likely to cause the inverted results to be quite unstable. In those cases. one might question whether the derived demand elasticity matrix is able to provide any meaningful economic information, let alone serve as a basis for verifying the counterpart of the inverse demand system.

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Books Reviewed

Alexandratos, Nikos, ed. *World Agriculture Toward 2000: An FAO Study*. New York: New York University Press, 1988, xx + 338, pp., $55.00.

This is a book prepared by a team led by Nikos Alexandratos, chief, Global Perspectives Studies Unit of the Food and Agriculture Organization (FAO). The book opens with a preface by Eduardo Saouma, director general of FAO. He explains the intent and the purpose of the book as follows: "It analyzes and as far as possible quantifies major changes likely to emerge in world agriculture, forestry and fisheries by the end of the century. . . . The study analyses and presents options for policy measures needed to meet the dual challenge of ensuring adequate supply and of improving access to food by all" (pp. xi–xii).

The book is a revised and updated version of "Agriculture: Toward 2000" which was submitted to the 1979 Conference of FAO and the shorter version published in 1981. What future is in store for mankind by the year 2000? Are the projections favorable? Were the assumptions and methodology used in making the projections realistic? What are the recommendations and guidelines that may be implemented to change the course of events? The book answers some of these questions.

The book is divided into eleven chapters and four appendices. Chapters 1 to 6 deal specifically with food and agricultural demand and supply analyses and projections. Chapters 7 to 11 concentrate on policy issues. The appendices contain statistical tables of the simulation results. The first chapter provides an excellent summary of the objective, methodology, and the results of the study. The central conclusion of the study is one of guarded optimism. "The FAO believes that agricultural development can continue to the extent projected without seriously damaging the world's natural resources. This assessment however carries a proviso: That more weight be given to environmental requirements in development policies and expenditures" (p. 25).

Chapter 2 reviews what has happened in world agriculture in the past twenty-five years. The heart of the study is chapter 3, where the methodology, empirical investigations, and the results are analyzed. The projections of demand, production, and trade are carried out for each of the commodities and countries analyzed individually. Chapter 4 examines the conditions that must be satisfied if the annual growth rates are to be met. Chapters 5 and 6 deal with the outlook for forestry and fishery demand and supply balances in the year 2000. Chapters 7 to 11 deal with the macroeconomic adjustments and institutional arrangements needed to solve the world "food equation" problem. The focus is on the third world. The aim is to analyze feasible changes that need to be made for the developing nations to meet the supply projections under socially acceptable growth rate with equity and without destroying the environment. To this end, strategies to deal with the problems of rural poverty, growth and equity, and rural industrialization are analyzed. For example, there is a discussion of how to find ways and means to "promote technologies that increase or sustain productivity at lower cost and do not harm the environment" (p. 237). The study concludes with a chapter that deals with the environmental aspects of agricultural development.

This, perhaps, is the most important and useful book that we have in the field of "global futures studies," on food and agriculture. It can be used by planners from developing countries to help them set production targets. It can also be used as a textbook in agricultural economics courses at the graduate level. Given the nature and scope of the subject, there are a lot of issues one can raise and disagree with. These may range from methodology to interpretations of the results. On the whole, the book is well written. Issues are raised and discussed at a high level of rigor.

Some readers, including this reviewer, may feel that the FAO experts are too optimistic about the future and may want to disagree or raise some questions about some of conditions and recommendations. Will we see a better-fed world in the year 2000? The FAO experts give a condition that should be met: "The production projections of this study are founded on feasible changes in input usage and involve adaption and transfer of existing technologies across regions" (p. 231). In the case of Africa, the FAO experts do not feel that this condition will be met: "To ensure the spread of new, improved technologies there is a primary need for extension and manpower training services and to assure access to them by the small farmer and landless laborer. Yet these requirements have been neglected in many parts of the developing world notably in Africa" (p. 230). World population is projected to grow at 1.6% per annum between 1985 and 2000 to nearly 6.1 billion, of which 4.8 billion will be in developing countries (p. 72). The FAO analysis requires a 60% increase in agricultural production in developing countries and 20% in developing countries for the next fifteen years. Will the third world be able to grow at this rate, especially Africa?

The consequence of population growth on the economic development of the developing countries is not well understood. Some economists consider long-term projections as speculative exercises rather than forecasts: Kelley has argued that "they are fraught with uncertainty arising from difficulties in predicting fertility trends and the fact that forecast errors cumulate over time" (p. 1092).

The recommendations for the forestry sector reads:

"Actual needs for fuelwood in the year 2000 could exceed projected. . . . A tree planting rate of 7 million per year in developing market economies would be required to meet these needs" (p. 166). In the fisheries sector, it is estimated that "total demand for fish by the year 2000, assuming no changes in relative prices or in the use of fish for fish meal, might well exceed 100 million tonnes" (p. 179). FAO hopes that with proper management the world could meet the supply projection and other conditions. Some environmentalists who view agriculture as a threat to the ecosystem will certainly disagree with the FAO study.

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Asian Productivity Organization. *Farm Finance and Agricultural Development.* Tokyo: Asian Productivity Organization, 1988, iv + 561 pp., price unknown.

This volume presents the proceedings of seminars held in Tokyo in 1985 and 1986 on farm credit. The main objective of the book is to disseminate findings and information generated in rural finance studies in Asia. The seminars included presentations and discussions of country statements, technical papers, and field studies addressing the state of Asia and Pacific rural credit, the role and performance of rural financial markets, mobilization of rural savings and default issues, as well as cross-country experiences and government credit policies. The book is organized in six major sections containing a total of thirty-one papers, and three appendices. Most of the contributors are scholars representing Asian Productivity Organization (APO) member countries, both the constituency and the intended audience of the volume. A few conceptual papers were prepared and presented by invited authors.

The volume succeeds in highlighting major issues in the region's financial markets, among others the need to foster deposit mobilization, to understand the importance of informal finance, and to better recognize the role of agricultural cooperatives in institutional lending. Loan recovery performance was singled out as the current most important concern, even though the section on default issues appears to be the weakest in the volume.

The key propositions of the so-called "new view" on rural finance are also well represented in the volume: (*a*) "Financial markets are vital in supporting development, but are largely ineffective when used to lead development efforts" (p. 37); in particular concessionary credit programs will not attain their intended goals while resulting in unintended and undesirable effects on the well being of the rural poor (*b*) Rural financial markets do not perform efficiently if agriculture is penalized through "low farm price and lack of investment in rural infrastructure" (p. 38) And (*c*) "rural financial markets work more efficiently, and certainly more equitably, when both lending and savings mobilization are emphasized" (p 38); indeed, rural savings are likely to increase substantially "if savings facilities are adequately provided in the rural areas" (p. 352). The need for appropriate financial policies and improvement of the overall quality of financial services provided in rural areas is the main corollary to the foregoing propositions.

In his paper Egaitsu draws a useful parallel between the "traditional" views on agricultural credit which the author labels the "farm finance" approach and the new "rural financial market" approach Egaitsu, along with Meliza Agabin and Tongroj Onchan, appropriately portray the limitations of the traditional approach in the region. Egaitsu and Agabin however. are more cautious in fully endorsing the new approach, their doubts apparently associated with the perceived presence of market imperfections in rural areas.

In addition to the conceptual papers indicated above Agabin's contribution on savings mobilization and Onchan's paper on farm credit policies are the highlights of this volume. The country studies, all essentially descriptive, vary rather widely in comprehensiveness and analytical quality. Most of the data reported are reasonably up to date, although the differing format makes cross-country comparisons difficult.

As a technical volume on rural finance and development, the book cannot compete with others, such as the volume edited by Adams, Graham, and Von Pischke or the recent textbook by Maxwell Fry However, the volume provides a useful discussion of key financial market issues in the region by highly qualified Asian scholars. The APO is thus successful in improving communications about rural finance problems among countries in the Asia-Pacific region Policy makers and donor agencies in the region will find this volume a useful reference.

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Adams, Dale W, Douglas H. Graham, and J. D. Von Pischke. *Undermining Rural Development with Cheap Credit.* Boulder CO: Westview Press, 1984.

Fry, Maxwell J. *Money, Interest, and Banking in Economic Development.* Baltimore MD: Johns Hopkins University Press, 1988.

Australian Bureau of Agriculture and Resource Economics. *Japanese Agricultural Policies.* Canberra: Australian Publishing Service, 1988, xiv + 359 pp., price unknown.

This book aims to fill an important void in the agricultural trade literature and does it quite well. Japanese agricultural policy is probably the least understood policy among high-income countries. This book provides a thorough description of the latest policy developments in Japan's agriculture and, in the process, reviews the most influential writings on the subject. The authors go beyond a cold definition of the policy instruments and integrate agriculture into the global economic system while taking into account the social and political contexts in which the Japanese agricultural policy has evolved. This kind of presentation makes the book more enjoyable to read and elevates it from a glorious collection of tables to an insightful document. The institutions are accurately portrayed as well as the regional realities of the country. In fact, while reading the book, one wonders how Japan's agricultural policy could be any different. The book is very effective in rationalizing the historical *cheminement* as well as the current state of the agricultural policy in Japan. This is undoubtedly the most important contribution of the book because it is hard to understand why the Japanese government and the Japanese people could tolerate such high levels of agricultural protection.

The book contains an extensive bibliography of almost everything ever written in connection with Japanese agricultural policy, including nonacademic publications. The work of experts on Japan's agricultural policy (e.g., Hayami, Hemmi, and Honma) is concisely summarized and is used to enrich the policy analysis subsections. The exposition is also enhanced by the numerous tables, figures, and maps used to support the discussion in the text. Every paragraph is summarized by small phrases beside the upper portion of the paragraphs.

The volume is divided into three main sections: (1) "Goals, Policy Instruments and Effects," (2) "Japan's Agriculture and Its Major Industries," and (3) "Issues in Adjustment." The first section is a broad description of Japan's agriculture. It is instructive but often appears repetitive. The discussion on protection does not differentiate trade-distorting subsidies from neutral subsidies and is restricted to the content of the corresponding tables. This is unfortunate because many potential readers are not trade experts. The first chapter in the second section should probably have been included in the first section. It is about the characteristics of Japan's agriculture and repeats many previously mentioned ideas. The remainder of the second section focuses on specific industries. The grain industries and the dairy, beef, sweetener, fruit, forest, and, finally, the fishing industries are extensively investigated.

Though the book covers a long list of topics, it is disappointing that an analysis or description of policies regarding pork imports is excluded. The Japanese market is very important for the United States, Canada, and Asian pork exporters and certainly deserves a few pages. Chapter 12 provides an accurate account of the problems between Japan, the United States, and the Soviet Union over fishing. However, its discussion of the Japanese fishing industries and environmental problems is rather limited. The last section of the book concentrates on the need for further reform and discusses how domestic programs and commercial policy should be altered to enhance the efficiency of the agricultural sector and minimize the repercussions on the international scene.

I strongly recommend this book as suggested reading for either undergraduate and graduate courses in agricultural trade policy. Its main advantage is its presentation. It is precise, clear, and very institutional in nature (perhaps at the expense of more thorough economic analysis). The findings of the most important papers and books on the subject have been incorporated in the various chapters in a manner conducive for learning. This book could easily be nicknamed "Handbook of Japanese Agricultural Policy," but it is clearly not a substitute for more technical books or articles.

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Barnett, Tony. *Social and Economic Development—An Introduction.* New York: Guilford Press, 1989, viii + 232 pp., $35.00, hardback $16.95 paper.

Agricultural economists working on problems of economic development are frequently reminded of the social, cultural, and political factors that influence change in third world societies. In the search for greater understanding of these factors, we often turn to sociologists, anthropologists, historians, and political scientists for insights. Barnett's book promises to provide some of these insights. Barnett, a professor in the School of Development Studies at the University of East Anglia, concentrates his efforts in this book "on sociology rather than on policy or development because I believe that sociology, together with its related discipline, anthropology, provides valuable insights into the problems of development in the 'Third World' . . . and in the so-called 'developed countries' . . ." (p. vi.). His emphasis is clearly on sociology, although economics appears in the title and is referred to throughout the text.

The book was written as a textbook for first-year sociology students and for more advanced students interested in the topic. The book is divided into three parts, with a total of ten chapters. It also contains a forward by James C. Scott, a preface, an afterward, a glossary, a bibliography, and an index.

Part I consists of two chapters and provides an introduction to the roots of sociology, the contributions of important sociologists of development (Saint-Simon, Comte, Weber, Durkheim, etc.) and the con-

cepts and theories of development used by sociologists. Most agricultural economists will recognize the names and works of Karl Marx, Max Weber, Talcott Parsons, Walt Rostow, and David McClelland (*n* achievement) among others. Brief introductions to the concepts and theories of utopianism, social solidarity, social evolutionism, functionalism, modernization theory, capitalism, Marxist sociology, and world system theory are presented. Historical examples and contemporary situations are used to illustrate the concepts and theories.

Part II, entitled "Town and Countryside," contains two chapters on urbanization and industrialization, two chapters on rural development, plus one chapter each on the role of the state and gender issues in development. The thrust of the chapters on urban-industrial development is on the growth, specialization, and class systems that accompany such development. Readers are reminded that many of the largest cities of the world are in third world countries. The development of contemporary third world urban-industrial areas is explained from both the Marxist and modernization perspectives. Import substitution programs and export-oriented industrialization are seen as trapped in a web of dependency relationships, transnational corporations, and the internationalization of capital. Rapid economic growth in Brazil, South Korea, Taiwan, Hong Kong and Singapore "has been based on massive state interventions and on all kinds of special conditions which, it could be argued, cannot be replicated in other countries" (p. 90). The call for a new international economic order (NIEO) is seen as a failed effort, and the reader is left with the impression that there are no future successful paths of urban-industrial development for the third world. Apparently, economics is not the only dismal science.

The two chapters (5 and 6) on rural development may be of most interest to agricultural economists. The transition of the rural sector from primarily subsistence activities to production for the market is the principal topic of these chapters. The simultaneous presence of market and nonmarket relations is explained using two competing social theories: *substantivism* or the theory that people organize their production and distribution activities on the basis of unchanging values and moral beliefs and *formalism,* which in its extreme form holds that all of social life can be explained by economic theory. Although Barnett claims that some sociologists and anthropologists embrace the extreme form of formalism, most development economists would probably choose the middle ground between substantivism and formalism.

The transition from subsistence to market production is viewed as drawing the peasant into the broader national and world economy and creating a class structure comprised of landless laborers, poor peasants, and rich peasants. The green revolution and agribusiness transnationals are held responsible for the creation of the new class structure. Agricultural economists familiar with the literature on the gree revolution are not likely to accept Barnett's conden nation of the green revolution.

The third part of the book contains a chapter o defining and measuring development and a fin chapter that includes "case material" based on te readings and a series of questions. Much of the di cussion of the meaning and measurement of deve opment seems out of place and probably should hav been included in the first part of the book. An a tempt to distinguish between GNP and GDP is n clear (p. 179), and the Gini coefficient is mentione as a measure of income inequality without any re erence or explanation of how it is derived or inte preted (p. 179). In general, although there are ampl references to economic concepts throughout the boo they are not well explained nor adequately refe enced.

Overall, this book is not likely to provide muc that is new for agricultural economists who alread have a general knowledge of sociologists' and a thropologists' theories and studies of third world d velopment. For those looking for an introduction t the material, this concise book covers a broad rang of topics. It presents both the Marxists and no Marxists thought, and it does a good job in clarifyin the diversity among rural and urban populations i the third world. This latter contribution may offs some economists' proclivity to assume homogeneit in responses to and impacts of changing economi incentives. The chapter on gender and developme provides a good introduction to the important gend issues associated with economic and social deve opment. It is unfortunate that the book does not i clude more use of and reference to the literature o economic development. For example, the discussio of the process of agricultural-industrial transform tion does not include the normal economic explan tion based on Engel's laws.

One disturbing feature of the book is the excessiv uses of "boxes" to provide examples or elaborate o certain points. Although, I generally like this writin technique, much of the information contained in th boxes could have been incorporated in the text or p in footnotes. Finally, this book is not likely to b used as a text in agricultural economics courses. Som professors who teach undergraduate courses on ec nomic development may want to select a few cha ters for use as required or supplemental reading.

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Coleman, David, and Trevor Young. ***Principles c Agricultural Economics: Markets and Prices i Less Developed Countries.*** **Cambridge: Cam bridge University Press, 1989, 323 pp., $69.5(**

The purpose of this book, according to the author is to equip its readers with the analytical tools an the theoretical basis for "solving the problems of ag

ricultural and rural development in poorer countries" (p. 2). It is one of the series of books developed by the University of London for its external postgraduate students in agricultural development. It deals with the principles, techniques, and applications of policy analysis in agricultural and rural development planning. It does an excellent job in its review of the basic economic principles and current theoretical issues and their relevance to the agricultural sector in the low income countries. The book is designed for use by teachers, students, and practitioners of the planning and management of agricultural and rural development.

To a significant degree, the book accomplishes its objectives. It is well written, organized, and appropriately sequenced. The book is organized around "the three main strands in the theoretical analysis of agricultural product markets—production, consumption and exchange" (p. 3). In each of these strands, the relevant economic theory and an excellent review of current theoretical debates are presented. These are generally followed by empirical applications and results presented in boxed illustrations.

The major strength of this book is its extensive review of economic theory in general and the synthesis of this theory to deal with policy issues in agricultural planning and rural development. This is best done in chapters 8, 9, 10, and 11. The discussions in these chapters are helped greatly by the empirical results and examples presented in boxed illustrations. This book is one of the few books that provides a good review of economic theory and discusses current and topical issues in third world agriculture and the practical dimensions to the analysis of agricultural policy in the less developed countries (LDCs). It does all of the above and yet pays attention to the practical limitations of the neoclassical economic theory in public policy decisions in the agricultural sectors of the LDCs.

The book has some limitations. One of the major weaknesses of this book is ironically related to one of its strengths mentioned above. In an attempt to review the major economic theory for the analysis of the agricultural sectors, exhaustive coverage of topics has been sacrificed for a broader review of theory. As a result, the analysis and discussions tend to be superficial and lack depth. For example, in the discussion of the marketing systems, the authors spend too much time discussing the competitive market structure, even though it has little relevance to the reality of the agricultural sector in most LDCs today. Instead, a detailed analysis and discussion of the side effects of imperfect markets and government interventionist policies in agriculture would have been more helpful to the practitioner of agricultural planning and rural development.

For a book designed for practitioners and policy makers, this volume is lacking when it comes to addressing some of the most critical issues facing the agricultural sector in the developing world today. For example, in discussing the determination of agricultural prices (chap. 9), the authors make no references or any serious attempt to discuss how agricultural prices in the LDCs are influenced by government interventionist policies. The authors assert that "prices farmers receive and the quantities they can sell are very much dependent upon the performance of firms above them in the marketing chains" (p. 19). In most LDCs, government policies such as price controls, concessionary interest rates, and input subsidies are important factors that influence price determination. Indeed, Mellor and Ahmed argue that "subsidy is treated as given at the time of formulation of product prices." Some of the critical and topical issues in the agricultural sector today in most LDCs, such as the effects on the agricultural sector of the World Bank-and the International Monetary Fund-supported structural adjustment programs, drought, technology transfer, and the environmental-production trade-off were not discussed at all in the book.

In chapter 11, while discussing trade theory, the authors fail to deal with trade barriers against agricultural products from the LDCs to the developed economies. No mention is made of the proposals contained in the "New Economic Order" that has been advocated by the LDCs to gain greater control in pricing their exports and playing a more active role in the world economy. It would have been appropriate and helpful if the authors had shown how these proposals would fit in with the neoclassical theory of international trade. The above weaknesses notwithstanding, I still find this book impressive. It is likely to be adopted by graduate agricultural economics programs, policy makers, and agricultural and rural development practitioners.

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References

Mellor, John W., and Ahmed Raisuddin. *Agricultural Price Policy for Developing Countries*. Baltimore MD: Johns Hopkins University Press, 1988.

Compton, J. Lin. *The Transformation of International Agriculture Research and Development*. Boulder, CO: Lynne Rienner Publishers, 1989, xi + 237 pp., $30.00.

This book was commissioned by the Experiment Station Committee on Organization Policy (ESCOP) of the National Association of State Universities and Land Grant Colleges (NASULGC) as part of the centennial celebration of the Hatch Act of 1887, which funds state agricultural experiment stations. It assesses the "transformation of the nature and functions of agricultural research and development institutions and their programs, describes the major changes, and identifies key trends and issues. It also documents the influence of U.S. initiatives on agricultural development and the relative effectiveness and efficiency of

various agricultural research and extension education strategies which have been tried in the developing countries." (p. 1)

The first section presents an assessment of the impact of national and international social, economic, political, and technological factors on the evolution of agricultural research and educational institutions in third world countries. It begins with a chapter that reviews the historical context of the evolution of the U.S. land grant system, focusing on the importance that mass political participation and a secure funding base had on creating a responsive land grant system, the relative absence of these conditions in third world countries, and the impact that U.S. development assistance efforts have had on parallel institutions in the third world. Forty years of technical assistance and development efforts in Peru are reviewed in the second chapter. The relative failure of these efforts is attributed to the lack of nontechnological conditions necessary for development to occur.

Part two of the book focuses on nontechnical challenges to agricultural development. It includes a chapter on conventional methods of communication of agricultural technologies, focusing on extension systems and scientists. This is followed by a discussion of women in agricultural development, factors related to these programs, and their lack of progress. The last three chapters of this section deal with conventional extension systems, such as the American system, and the need for agricultural scientists and educators to give greater attention to indigenous agricultural systems in order to address better the needs of small farmers.

The last section includes an analysis of international agricultural research centers and farming systems research and extension models as potential guides for advancing agricultural development in the third world. Vern Ruttan summarizes the evolution of international research during the past four decades, focusing on organizational and management issues. He also questions the ability of U.S. universities to contribute effectively to applied research in the tropics. The development and use of farming systems is described in the final chapter. The discussion focuses on the importance of involving small-scale farm producers and their families in research and development aimed at generating appropriate technology.

The book is a contribution to the development literature, particularly that which deals with agricultural institution building in the third world. Most of the ideas found in it are not new, having been presented and discussed elsewhere by the contributing authors and others. However, nowhere have they all been summarized within the context of the U.S. land grant system, its core activities, and its contributions to agricultural development in other countries. This alone makes it a useful addition to personal and institutional library collections.

Development administrators and students of third world agricultural development will benefit from reading the book. Compton competently summarizes the contents of each section, identifies and expanc on the major themes of individual chapters, and higl lights points of intersection among them. His insigh guide the reader through individual sections and serv as useful tools for review.

I found the book to be an excellent summary c past and present contributions of the land grant sy tem to international development efforts, particularl those supported by bilateral and multilateral donor It illustrates the obvious limitations of the U.S. lan grant model to promote agricultural development i the third world. Its major shortcoming is the lack c a concise and critical discussion of what the U.S model really has to offer to these countries. But, ther Compton may have decided to let the reader decid this.

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Fuller, Wayne A. ***Measurement Error Models.*** **Ne York: John Wiley & Sons, 1987, xxiii + 44 pp., $44.95.**

A measurement error is made when the observe variable differs from the true variable. For exampl suppose one wants to predict corn yield as a functio of available soil nitrogen. One must sample the so of the experimental plot and do a laboratory analysi of the sample. The resulting observation on soil ni trogen will be only an estimate of the unknown tru value. Use of standard statistical techniques can yiel significantly biased and inconsistent estimates of th parameters of a model when measurement error i present. *Measurement Error Models* was written i order to increase the use of statistical techniques ex plicitly recognizing the presence of measurement er ror. The author suggests the book may be used as text for a graduate course concentrating on statistic analysis in the presence of measurement error or a an auxiliary text in courses on statistical methodo ogy. The book should serve these purposes well, bu it will be even more useful as a reference for re searchers.

Psychologists and sociologists have long recog nized that their data included measurement or re sponse error, perhaps because their data were so di rectly collected from human subjects. Tradition economic variables, such as age, income, educatior and unemployment or poverty status, can also b strongly affected by response bias. Fuller shows th 50% of the mean square error can arise from respons bias in reasonable sample sizes.

Least squares estimates of parameters in model that contain variables measured with error are biase and inconsistent because the equation's error term i no longer independent of a regressor. Judge et al. also in the Wiley series in probability and mathe matical statistics, present an excellent overview c estimation procedures for models containing errors i variables (p. 510), but Fuller expands considerabl

on the subject, giving computational formulas, numerical examples, crucial theorems, and their proofs.

Chapter 1 introduces the problems of measurement error when there is a single explanatory variable. Careful distinction is made between models in which the independent variable is fixed and models in which the independent variable is random. The reliability ratio is explained using examples from genetics. Knowing the reliability ratio, one can construct an unbiased estimate of the beta parameter and perform the usual hypothesis testing.

In general, the properties of the estimators corrected for the measurement error depend on the type of information that is available to identify the model. Some additional information, such as the reliability ratio or the variance of the measurement error, must be available or an equation with errors in the variables cannot be identified. Fuller gives the appropriate formulas to calculate parameters, significance tests, and confidence intervals, correcting for measurement error. He supports most of the formulas with excellent numerical examples. The chapter concludes with brief sections describing what to do when x is not normally distributed, how to use Wald's grouping technique, and the importance of measurement error if the objective is prediction.

The second chapter extends the results of the first chapter to models with more than one independent variable. The calculations become more formidable in this section, and Fuller recommends appropriate statistical software. One section is devoted to the small-sample properties of estimators and to modifications one can make to improve small-sample behavior.

Chapter 3 relates the classical regression assumptions, specifying appropriate formulas when errors are heterogenous or non-normally distributed, and for models with multinomial random variables. The latter occurs when the observation process consists of assigning each member of a sample to one of r categories. An example is the reporting of employment status.

The final chapter extends the treatment of measurement error models to the case where true variables satisfy more than one linear equation. It concludes by expanding the simple factor model of chapter 1, where elements of an observation vector were linear functions of a single unobserved factor, to higher dimensions.

Each chapter contains exercises and references. There are helpful lists of examples and of principal results at the beginning of the book, features more textbooks ought to contain.

I have only a few minor complaints. First, a two-page appendix on notation follows the first chapter; it should precede it. Second, the first ANOVA table appears (p. 135) with insufficient information; a reader unfamiliar with ANOVA cannot understand it. This flaw stands out because the author is generally so extremely careful to assume no more than standard regression knowledge in his readers. Third, many of the calculations are performed using the SUPER CARP program. It would be nice to see a few sample programs.

This book condenses and synthesizes fifty years of measurement research. It is an authoritative summary because much of the research in the last fifteen years was done by Fuller. It is an immense help to someone who needs to use a measurement error model. Without this book one would have to master an extremely large and scattered set of published articles, each with a different notation and—if from the psychology literature—written in an alien tongue.

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References

Judge, George, William Griffiths, R. Carter Hill, and Tsoung-Chao Lee. *The Theory and Practice of Econometrics*. New York: John Wiley & Sons, 1980.

Greeley, Martin. *Postharvest Losses, Technology, and Employment—The Case of Rice in Bangladash*. Boulder CO: Westview Press, 1987, xvii + 345 pp., $35.00.

This is a scholarly and penetrating book. It effectively rewrites a chapter in the annals of development thinking. At the same time, it puts out in the cold one of the more profitable "milking cows" of the development game.

Throughout the 1970s a whole industry grew up around postharvest losses in developing countries. These were allegedly both excessive, typically estimated at 10%–15% at least (which, anyway, is about the amount that goes over the back of an average combine harvester), and remediable, by the application of Western technology and development assistance. Professional reputations were built, the programs of whole institutes were justified, high-level committees were indulged, hundreds of millions of dollars were invested by development agencies, and considerable profits were made, all in the effort to combat this egregious shortcoming in the competence of peasants.

This book presents a Bangladesh case study of the farm-level postharvest system, based on meticulous fact gathering over three years. Using the measurements obtained, together with supporting information from other sources, the author tests, and rejects, the conventional assumptions that farm-level postharvest losses are large, that they can be prevented cost effectively by technical change, and that as a consequence there will be more food consumption by hungry people.

Having demonstrated rather convincingly that none of these assumptions is true, and why, the author goes on to examine farm-level technical change in postharvest practices in Bangladesh. He concludes that these changes are reducing food availability, reduc-

ing the number of work places, and are damaging to the welfare of some of the poorest rural households. Further analysis is used to explain farmer adoption of these technical changes in terms of cost savings, to explore social costs and benefits that they give rise to, and to suggest the types of intervention that might be appropriate.

Chapter 1 of the book is introductory. Chapter 2, entitled "The Postharvest System and World Hunger: The Debate on Neglect and the Neglects of the Debate" examines the conceptions and misconceptions concerning the role of postharvest food loss in the fight against hunger. It is argued that the advocates of loss prevention programs were aware of the unreliability of available loss estimates but nevertheless used them, often selectively, to support their case.

Chapter 3 describes "Rice in Bangladesh: The Farm-Level Postharvest System" in careful detail. It provides working definitions of postharvest and food losses, and emphasizes "measurability, sound definition and economic valuation" of quantitative loss assessments. It includes, *inter alia,* a comprehensive account of rice culture in Bangladesh.

The main evidence on food losses is presented in chapter 4, "Bangladesh Farm-Level Food Losses: The Evidence Against the High Loss Lobby," most of which is devoted to a discussion of the loss assessment methods employed in the study. The losses measured provide detailed evidence that farmers are efficient in avoiding postharvest losses, and that what does occur (mainly in storage) is unavoidable in terms of cost-effective farm-level loss prevention interventions.

Chapter 5, "Technical Change: Pedal Threshing," shows that despite the fact that pedal threshers cause higher food losses, they are still a profitable investment for machine owners and renters because of the substantial reduction in labor hours per ton. But the interesting feature is that the labor saved is all family labor, which is attributed to family labor constraints, machine-owner monopoly control of labor used, and growing farm management requirements of family labor. This latter point is discussed persuasively, and at some length, but without a definite conclusion.

Chapter 6, "Technical Change: "Rice Milling," examines the replacement of manual rice husking by the huller rice mill, with some one-third of on-farm rice consumption being mill-processed in the mid-1980s. The author notes no differences in food availability with the new technology because milling losses are recovered in subsequent cleaning and sorting practices. The female wage labor loss is judged more serious. Cost-benefit analysis shows the rice huller to be more profitable than manual husking at market and efficiency prices, but once social weights are introduced the manual method is very much more profitable.

The final, chapter 7, "Policy Implications: Programmes for Rural Women," builds on the results of chapter 6 and departs from the main theme of postharvest food loss. It argues for special programs for rural women, to substitute for the employment lc through technical changes, as the likely more effe tive policy response in the face of current trends. Tl universality of the female labor displacement patte is emphasized. The potential of development pr grams for wage labor women to address both gend issues and poverty issues concurrently and effective is strongly argued. These arguments are supported l field evidence.

One cannot but be impressed by the rigor, tran parency, and relevance of the work this book co veys. The study is a model of applied empirical ana ysis that many students might well emulate. The bo itself is well written, readable, and devastating. Tl author deserves the highest accolades of our profe sion.

The book is strongly recommended as an antidc for anyone inclined to organize another task-forc workshop, or international conference on postharve losses—and less costly too!

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Lofchie, Michael F. ***The Policy Factor: Agricu tural Performance in Kenya and Tanzani*** **Boulder CO: Lynne Rienner Publishers, 198 xi + 235 pp., price unknown.**

This is an interesting and useful book. It provides readable account of the external and internal facto that seem to explain the serious food and agricultu problems that have emerged in sub-Saharan Afri during the past two decades. The emphasis on co paring "the economic performance of an agricultu ally successful country, Kenya, with that of an a ricultural failure, Tanzania" is appropriate and mak it possible to go beyond a journalistic account of t African food problem and associated causal facto

An especially valuable contribution of the book in making available U.S. Department of Agricultu time-series data, typically annual estimates for t 1966–86 period, comparing production and yield e timates for major export, industrial, and food crop Those tables and accompanying diagrams, which ma it easy to compare the performance of the two cou tries, confirm Lofchie's summary conclusion abc success and failure. He recognizes that these es mates are subject to a considerable margin of errc with food production statistics for Tanzania bei expecially unreliable. The performance contrasts a most striking, however, for export crops for whi supporting evidence from trade statistics is availabl (Even the export statistics are subject to qualific tion, because of illicit exports from Tanzania and b cause Kenya's export figures may include some cc fee or other produce smuggled into the country fro Uganda or Tanzania.)

Although Lofchie acknowledges that external fa tors, notably the Uganda War and the sharp increas in petroleum prices in 1973 and 1979, contributed

Tanzania's economic decline, his emphasis is on the effects of internal policies and the interacting effects of declining exports, balance of payments deficits (aggravated by increased food imports as well as the rise in oil prices), inflation, extremely low rates of utilization of the country's industrial capacity, and a severe debt crisis. Major attention is given to four policies that had "ruinous impact on the country's once-thriving agricultural system: (1) overvaluation of the currency; (2) suppression of agricultural producer prices; (3) implementation of agricultural policy through a system of monopolistic parastatal corporations; and (4) pursuit of an industrial strategy based on the principle of import substitution" (p. 119). Again, the book provides a convenient source for data that the USDA has compiled on official prices for major commodities in each country, plus price series adjusted for overvaluation on the basis of parallel market exchange rates together with price ratios for the two countries based on those adjusted prices. Unfortunately, the series for coffee and tea extend only to 1979/80; the figures for corn and several other food crops extend to 1986.

The book is in general the well-informed account that one would expect of an author who is director of UCLA's prestigious African Studies Program. There is one surprising error in giving Tanzania's date of independence as 1966 instead of 1961 (p. 70). There is also a tendency for the author to be unrelenting in his criticism of Tanzania's policy makers, whereas he sometimes seems to lean over backward to offer a favorable interpretation of decisions by Kenya's policy makers.

As an economist, my principal criticism of the book is its failure to distinguish clearly between activities, for example the provision of public goods such as agricultural research, for which public sector intervention is likely to be critically important, and other types of activities for which competing private firms (and independent coops) have a comparative advantage. Lofchie notes that Kenya's Tea Development Authority (KTDA) was "an exemplar in fostering smallholder development" (p. 166). But he fails to point out that the KTDA was a significant institutional innovation because it enabled smallholders to produce high-quality tea for export by carrying out those activities—especially prompt collection and processing of tea leaves—for which economies of scale are important. Prior to that innovation tea had been regarded as a "plantation crop" par excellence.

It also should be mentioned that Lofchie, a political scientist, makes a surprisingly limited contribution to explaining why Kenya's policy makers opted for an appropriate agricultural strategy whereas policy makers in Tanzania pursued policies that had disastrous consequences. He relies mainly on an "urban bias-weak state paradigm" that is based on Michael Lipton's *Why Poor People Stay Poor* and Robert Bates' *Markets and States in Tropical Africa*. The fact that the book had a long gestation period probably accounts for the fact that he does not draw on a fairly recent book by Richard Sandbrook (1985) which, in this reviewer's opinion, adds considerably to the insights that can be derived from Lipton and Bates.

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Reference

Sandbrook, Richard, with Judith Barker. *The Politics of Africa's Economic Stagnation*. Cambridge: Cambridge University Press, 1985.

Luttrell, Clifton B. *The High Cost of Farm Welfare*. Washington DC: The CATO Institute, 1989, xi + 149 pp., $19.95 hardback, $9.95 paper.

The combination of this book's title and its publisher should be sufficient to alert the reader that an attack on government involvement in agriculture is forthcoming. Of course, there is nothing wrong with that and the criticism may be well deserved. Luttrell, an agricultural economist with the St. Louis Federal Reserve Bank for more than thirty-five years, has offered a short (i.e., 130 pages of text and tables), highly-readable summary of the history and economics of government agricultural programs in the United States. Given the length of the book and its broad scope, some of the analysis is necessarily superficial—indeed, in some cases too oversimplified, e.g., "the increasing liberality of FmHA lending on farmland in the 1970s led to spiraling land values" (p. 78)—but much of the analysis is difficult to argue with, at least for market-oriented economists.

Luttrell traces the history of federal government agricultural programs from initial limited involvement in such areas as farmer education and support for farm cooperatives through the development and rapid expansion of price support and supply control actions in the 1930s to the "alphabet soup" of payment-in-kind (PIK) and dairy buyout (DTP) programs of the 1980s. Among the eleven chapters are those on the New Deal farm programs, supply management, surplus problems and export subsidies, food stamps, farm credit, the dairy and sugar programs, and farm poverty. Most of this will not be new to any professional economist, but it offers a good summary of the various programs.

Essentially, Luttrell's position is conventional. He argues that many of the support programs increased returns to farmers in the short run (although at very high cost) but generally provided incentives to increase production. Combined with the capitalization of the subsidies into land values (with all that implies for higher land costs), this tended to drive average returns to normal in the long run. The net effect has been to attract or maintain excess resources in agriculture. Thus, it is argued that these programs failed in their primary objective and have done so at substantial deadweight cost. Luttrell argues that this failure to increase farm income then provided the basis

(i.e., "low" farm income) for another round of even higher-cost programs.

> The simultaneous existence of large government expenditure on farm programs in the mid-1980s with relatively small impact on net farm income (realized government losses in some years exceeded net farm income and USDA expenditures were two or three times net farm income) confirms this principle of ineffectual subsidy ratcheting. (p. 121)

Published estimates of the annual deadweight loss of federal subsidy programs [ranging from $1.5 billion to the $5.2 billion (Council of Economic Advisors)] are criticized because of their focus on short-run effects only. Using some "quick and dirty" economics that include long-run effects, Luttrell concludes that the annual deadweight loss is more than $30 billion. While one can quibble about the magnitude, there is little question that the loss is substantial.

The book also summarizes some of the evidence indicating that many of the agricultural subisdy programs violate the conventional notion of vertical equity. That is, the income transfers are from lower to higher income individuals. If the farm problem is really one of poverty, Luttrell argues that $2 billion per year in direct income transfers to farmers whose net farm income falls below the official poverty line would eliminate the farm poverty deficit which currently is at least partially if not completely offset by off-farm income. Alternatively, if the objective is somehow to maintain an agrarian society as it exists today, he suggests that all farm programs be dismantled over a five-year period and the adverse short-term income impacts mitigated by making annual payments to farmers of 50% of their annual average net farm income for the past three years. These payments would be made until the farmer reached age seventy, with appropriate adjustments for inflation. The 1987 cost of this program, about $15 billion, is about half of Luttrell's estimate of the social cost of the existing arrangement and has the advantage of declining each year as some farmers reach age seventy and phase out of the program. In forty or fifty years the cost of this program would reach zero as all existing farmers attained the "retirement" age.

This book is certainly timely. While it is possible that the economic structure and conditions facing agriculture at the depth of the depression justified some sort of significant government support program, the situation in 1990 is far different. The programs we have now may have been suited to an era of fifty years ago, but Luttrell makes a strong case that they are not appropriate to today's agriculture. Of course, some already have spoken plainly about the need to reorient the system. (For example, see the interchange between Tweeten and Knutson.) The pressure to reduce federal government spending, the continuing shift of political power away from rural areas, and a public awareness that many of these programs are socially inefficient probably will continue to threaten agricultural subsidy and control programs.

This book has not been written for the mainstream agricultural economist (although many will enjoy reading it), but it may very well find a niche on the reading list of the typical agricultural policy course. Although not a balanced treatment of the problem, it provides a good bit of history, it is definitely thought provoking, and even a slow reader can get through it in a couple of hours. Some, perhaps many, may disagree with the Luttrell position; but, clearly, he speaks for a growing number of people both inside and out of the agriculture establishment.

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Mitchell, Robert Cameron, and Richard T. Carson. *Using Surveys to Value Public Goods: The Contingent Valuation Method.* Washington DC: Resources for the Future, 1989, xix + 463 pp., price unknown.

In his forward, Raymond Kopp (p. xv) explains that this book "provides decision makers, policy analysts, and social scientists with a detailed discussion of a new technique for the valuation of goods not traded in private markets. Termed contingent valuation, the technique draws upon economic theory and the methods of survey research to elicit directly from consumers the values they place upon public goods."

Mitchell and Carson's blend of economics and survey methodology, together with liberal doses of sociology, should make their book a welcome addition to the literature on contingent valuation (CV). Specialists in that technique may quibble about numerous points. Nevertheless, this is the best book available on the topic.

The first five chapters introduce CV. Some of the topics covered include the welfare theory underlying valuation, valuation under uncertainty, the advantages of CV compared to other techniques, alternative CV question formats, the theoretical merits and practical usefulness of referenda questions for valuing public goods, existence value, and possible theoretical relationships between willingness to pay and compensation demanded.

A particularly noteworthy contribution of the early chapters is an exposition of the dual concepts of reliability and validity as they apply to CV. Many have voiced skepticism about the accuracy of the technique. Feeling the need to address these concerns in

a more systematic way, early CV researchers conceived of a number of potential "biases" that could have been present in their studies. One paper on the topic (Schulze, d'Arge, and Brookshire), for example, spoke of strategic, hypothetical, information, and other biases. This was an important step in the history of CV because it assigned names to the concerns of the skeptics and thus set the stage for empirically addressing those concerns. However, the term "bias" was not clearly defined, and the boundaries between the various "biases" were not always apparent. The concepts of reliability and validity have served well in addressing measurement problems elsewhere and, as developed by Mitchell and Carson, represent a promising avenue for systematically and rigorously investigating the accuracy of CV.

Chapters 6 through 9 survey evidence related to the reliability and validity of CV. Concerns about the willingness of people to respond accurately to CV questions stem directly from Samuelson's argument that people have an incentive to behave strategically, rather than telling the truth about their values for public goods. Based on a detailed review of the public goods literature, the authors conclude: "The evidence for willingness to pay . . . suggests that strategic bias is not a significant problem for CV studies under *most* conditions. Instead of being a fundamental, unavoidable threat to the CV method, strategic behavior is just one of many possible sources of bias which the designer of a CV study must take into account" (p. 170).

The ability of study subjects to give meaningful responses to CV questions is the next topic addressed. Concerns here have focused on the ability of respondents to predict in surveys how they would behave in a market setting or a voting booth were they confronted with real opportunities to affect the availability of recreational, environmental, or other commodities or services and the amount they would actually pay. For decades, social psychologists have been investigating whether "behavioral intentions" and other attitudes, as expressed through surveys and other media, can be used to predict behavior. The conclusion to be drawn from Mitchell and Carson's survey of the attitude-behavior literature is somewhat optimistic: The CV researcher is investigating a form of behavioral intention that could be a fairly accurate predictor of behavior, but pitfalls exist that must be guarded against through careful survey design. Quoting them (p. 188) directly, "The key problem facing the designer of a CV study . . . is the novelty of valuing a public good, given the respondents' varying degrees of familiarity with the good being valued and how they currently pay for its provision."

In chapter 9, Mitchell and Carson examine experimental studies on the validity of CV, concluding that the results generally support its accuracy when it is used to measure willingness to pay. In the process, they further develop the concept of validity in a way that future researchers will find very useful.

Chapters 10 through 12 provide explicit advice for designing CV studies. Chapter 10 reviews some ways to enhance reliability, including ways to deal with the thorny problem of outliers. Chapter 11 categorizes ways in which systematic errors might threaten the validity of contingent valuation results. Mitchell and Carson significantly improve upon previous work by predicating their discussion on assumptions about human behavior that are more realistic than the assumptions underlying *homo economicus* and by making positive suggestions, based on general experience in survey research, for avoiding problems. Chapter 12 provides sound advice on sampling and aggregation issues.

Chapter 13 presents the conclusions of the book. Its centerpiece is a list of criteria for evaluating CV studies, which is more thoughtfully conceived and empirically grounded than the "reference operating conditions" offered by Cummings, Brookshire, and Schulze (p. 104).

The usefulness of this book extends to its appendices, which summarize the content, form, and other details of more than 100 CV surveys, present one of Mitchell and Carson's own surveys as an illustration, and discuss statistical aspects of hypothesis testing and experimental design. The bibliography is composed of fifty-three pages of useful references.

Researchers whose work is cited in this book may find a few "flies in the ointment." I certainly did in their treatment of some of my own work. Regardless, Mitchell and Carson have succeeded in their "attempt to contribute to an understanding of what constitutes best practice in contingent valuation surveys" (p. 299). Their book should serve as a valuable research reference and teaching tool for many years to come.

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Molnar, J. J., and H. Kinnucan, eds. *Biotechnology and the New Agricultural Revolution.* Boulder CO: Westview Press, AAAS Selected Symposium 108, 1989, 288 pp., price unknown.

This volume is the edited proceedings from a 1986 symposium at the annual meeting of the American Association for the Advancement of Science. The

preface (p. xiii) notes, "The papers are intended to provide some understanding of the ways biotechnology is reshaping agriculture—research, regulation, and production—and the major directions that can be anticipated." The volume itself is organized in a slightly different fashion with the three parts titled "Institutional Issues," "Shifts in Farming and Agriculture," and "International Perspectives." These headings encompass a total of ten papers plus an introduction and conclusion by the editors. The work is well indexed and contains an impressive list of references.

Life, experience and research tell us, tends to move in cycles, and so it has been with attitudes toward biotechnology. From incredulity following the first announcements of gene splicing, the public and business went through a period of euphoria, when biotechnology was seen as solving all problems. Doubts emerged as the technology advanced more slowly than suggested. Environmental concerns also surfaced as a largely new class of products were poised for full release. Subsequently the public seems to have moved to a more balanced wait-and-see attitude to the technologies and their likely impacts, both positive and negative.

The bulk of papers in this volume fit solidly in the period of rising doubts about biotechnology. The tone is set by the twelve-page introduction, of which one describes in general terms the potential benefits of biotechnology while eleven raise concerns. The concerns addressed fall into three major categories: input supply concentration, safety and regulation, and farm structure. The treatment can be described as being predominantly sociological. That is true even though the contributing authors and papers are split evenly between sociologists and economists (two additional papers are more production based). However, one of the economics papers is, for an audience of agricultural economists, a general overview of the adoption literature, while another—an examination of the competitiveness of U.S. agriculture as revealed by patent records—is a substantial effort but has little to do with biotechnology. The number of biotechnology patents at the time of writing was simply too few to draw any real conclusions. Thus, the overall impact of the volume is more one of social analysis than economic.

For economists, it is often beneficial to be exposed to different interpretations of the implications of technological change. Nonetheless, I find much of the treatment here incomplete. For example, the Kenney paper takes a largely conspiratorial view of regulation: "In fact, most public representatives and legal counsel warned industry that the public required the 'perception' of regulation and that real regulation was not necessary" (p. 92). Undoubtedly that is an aspect of the regulatory environment, but by no means all of it. Indeed, a case can be made that some aspects of biotechnology are too effectively regulated. In their discussion of the impacts of biotechnology on the division of research between industry and universities, Lacy and Busch claim: "The division of labor has been until the present, fairly clear" (p. 31). In my experience, the relationship between agribusiness and universities has never been really clear. The feeling of incompleteness is enhanced by the two production-based papers. Brady, writing on biotechnology applications to developing-country agriculture, really gives a litany of USAID projects. And Terrill's contribution on biotechnology in livestock production is perplexing in its focus on small ruminants. "The potential to increase efficiency of small ruminant meat animals through biotechnology selection research is so great that it will be difficult for any other technology to have a practical impact on farm production" (p. 112). That statement overlooks much exciting work which had been done on small mammals and is potentially extendable to the major red meat species.

Part of what is happening is the rapid advances made since these papers were written. They have become somewhat dated despite obvious efforts to extend the references. As examples, there is a reference to the delayed field testing of ice-minus bacteria, which has subsequently been tested (with no apparent problems) in the environment. Buttel and Geisler (p. 145) raise questions about the adoption predictions of bST given some evidence of lower responses in the South. Subsequent research has shown equivalent milk production response when common heat stress-reducing practices are followed (Bauman, personal communication). It should be noted that three of the papers focus on bST which then, as now, is one of a very few biotech products that is likely to have a major impact on agriculture in the near term.

But these are minor points. More substantively, one can consider the paper by Geisler and DuPuis, which notes the policy and attitude changes in extension and other programs needed "if the adoption of bST is not to be a self-fulfilling prophecy in terms of distributional effects . . ." (p. 229). They proceed to describe programs directed to "exit prevention," the avoidance of prejudging farmers as progressive or not, and the use of multitiered price supports. Many of these points are well taken, and some states—certainly here in New York—are already working to enhance the potential for successful adoption of bST among their dairy farmers. But at the extreme, these writers are proposing a fundamental change in the operations of the U.S. agricultural sector away from market forces and toward more managed structural change. Such a step may indeed be appropriate, but the problems and limitations require far more attention than they receive here. Geisler and DuPuis, for example, describe the merits of Japanese land tenure and extension systems in promoting a "unimodel farm-size distribution" and "relatively efficient small family farms" (p. 236). No mention is made of the horrendous subsidy cost of that system.

Proceedings papers by their nature tend to be disparate. It is the challenge to the organizers/editors to coordinate the papers as a whole prior to presen-

tation or to interrelate them in the conclusions to the published proceedings. Molnar and Kinnucan, while noting that "biotechnology is only one of many sources of change in agriculture . . ." (p. 254), do not provide a volume which integrates biotechnology into the dynamics of the agricultural sector. The sum does not exceed the total of its varied parts.

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Morales, Edmundo, *Cocaine—White Gold Rush in Peru*. Tucson: University of Arizona Press, 1989, 228 pp., price unknown.

Morales, a Peruvian with a doctorate in sociology from the City University of New York, is an acknowledged expert on cocaine production and trafficking. He employed an ethnographic research method in developing the data base for his book. He interviewed more than 100 families in a town near his birthplace in the Andes of Peru, more than 70 coca paste workers, and another 150 persons connected with the cocaine economy.

Morales questions what economic force will replace coca. The purpose of the book is to suggest alternative means of making a living for impoverished populations currently supporting the cocaine black market.

Prior to addressing the major purpose, he offers three chapters on traditional uses of coca leaves, the physical setting and demographics of coca agriculture, coca culture, and the cocaine economy.

The chewing of coca leaves, beginning perhaps about 1800 B.C., is associated with work situations, rituals, and religious practices. For centuries landlords, mine owners, and other employers have served coca leaves to their workers as a measure of social control. The chewing of coca increased the vigor and morale of workers. Coca chewing is believed to raise individual spirits, ward off hunger, reduce fatigue, and, by many, to resolve health problems.

The second chapter reviews important information relating to the severe economic conditions of the Andean region of Peru. The unsuccessful land reform of 1969 raised expectations but had little impact on real incomes. Even large outmigration, to Lima and other coastal cities, has not altered the level of economic opportunities. More migration to the high jungles of Peru involved large numbers and extensive participation in the illegal coca economy, annually adding $2 billion in Peru and $80 billion worldwide. Agriculture developmental alternatives (coca substitutes) in the high jungle (tea, coffee, cacao, rice, corn, etc.) have been limited due to the lack of infrastructure, markets, technology and its transfer, price controls, and poor environmental conditions.

The next chapter describes the production of coca plants. Harvests are made five times a year beginning one year after transplanting and continue for twenty-five–thirty years. The high quality Peruvian coca plants require no fertilizer, very low maintenance inputs, and perform well on poor soils, steep hillsides, and high elevations with heavy or light rains.

Recently, Peru has annually produced 100,000 hectares of coca yielding 160,000 metric tons of dried leaves. Some 5,500 metric tons are consumed by coca-chewing Andean Indians and peasants, leaving 96% to the illicit economy.

Coca leaves are treated to extract alkaloids by producing coca paste. The coca paste transformation requires four chemical agents, sulfuric acid and sodium carbonate, that move within Peru through the underground economy. The other two are calcium oxide (unslaked lime) and kerosene, readily available throughout the high jungles. This cottage industry has modest capital requirements but is dependent upon a good chemist or an experienced mixer. The underground coca paste economy is well organized and includes an outside boss, international linkmen, a local boss, his bodyguards, and collectors of coca paste along with a transport/security support staff.

Through an elaborate trafficking system, the coca paste reaches laboratories for conversion to cocaine hydrochloride. This process requires a capable chemist working with hydrochloric acid, acetone, and ether.

Annually, the 160,000 metric tons of coca leaves in Peru can produce 1,500 metric tons of coca paste. This paste converts to about 400 metric tons of uncut cocaine hydrochloride. A kilo (2.2 pounds) of cocaine may cost some $5,000 to produce and transport, has a New York wholesale price of $35,000 (50% purity) and can yield retail sales of adulterated cocaine of $200,000.

Morales characterizes the Peruvian underground cocaine economy as a cosmetic modernization of the countryside. The industry is subject to, and completely dependent upon, internationally organized crime. The White Gold Rush does not support a sound, healthy, and independent national economy. There are increasing problems of urban and rural addiction along with growing levels of official corruption.

Prior to addressing his major purpose, alternatives for impoverished people, the author attacks the myth of the alliance of two undergrounds. The cocaine underground is a social organization with pure economic interests, while the terrorist underground is a fanatic political ideology structured to resolve social injustices. The alliance is unreal in that the illicit economy cannot afford to support political movements that do not lead to accumulated wealth.

Turning to U.S. efforts in Peru to reduce coca leaf supply, the author argues the U.S. policy is, and will continue to be, ineffective. U.S. efforts to eradicate and interdict supply and to support crop substitution and plant destruction are incorrect policies.

The author argues that a more rational use of the billions now used in unsuccessful programs would be a rational and authentic economic development program in the coca leaf area. Large investments in infrastructure, markets, rational policies, technology generation and transfer, education and health would be required.

Other suggestions for U.S. collaborative actions,

not his own, focus on stricter law enforcement on producers and gateway nations along with consideration of a program to purchase and destroy coca leaves. Another direct U.S. action should focus on enhanced educational programs to reduce the demand for cocaine.

The book is well written and should be of interest to people impacted by the coca industry and concerned over alternative U.S. actions.

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Rasmussen, Wayne D. *Taking the University to the People: Seventy-Five Years of Cooperative Extension*. Ames: Iowa State University Press, 1989, x + 300 pp., $24.95.

This book was commissioned by the Extension Committee on Organization and Policy (ECOP) to commemorate the seventy-fifth anniversary of the Cooperative Extension Service. Its purpose is described by the members of the Seventy-Fifth Anniversary Book Task Force in the foreword: "A history of the evolution of Extension is of some importance at this point in its life cycle. But, more important, a modern text detailing the unique characteristics, evolution of methodologies, and current institutional changes under way in the Cooperative Extension System is the more pertinent document" (p. xviii). Funding for this project was provided by Extension's supporting organizations, including partners in the Extension system who guaranteed advance orders in excess of ten thousand copies.

Given the nature of the charge and the sources of funding, it should come as no surprise that *Taking the University to the People* is not an objective evaluation of the strengths and weaknesses of Extension. Rather, it focuses overwhelmingly on Extension's strengths and successes. Any evaluation is mostly a rehash of the ECOP Futures Task Force Report; therefore, evaluations of that ECOP report by Henderson and Wallace are also applicable to this book. In spite of its lack of objectivity. *Taking the University to the People* is a carefully researched and scholarly work about the history of Extension.

Following brief references to the Morrill Land Grant and Smith-Lever Acts, chapter 1 provides a brief overview of Extension as it exists today. Rasmussen carefully walks the reader through the federal, state, and county partnership and its linkages to the USDA and land grant universities. He also outlines Extension financing, staffing, and supporting organizations. The introductory chapter concludes with descriptions of Extension's researched-based educational programs in the United States and imitated, but less effective, programs around the world.

Chapters 2 and 3 trace Extension's roots from George Washington's support for agriculture in 1796 through the passage of the Smith-Lever Act in 1914. Rasmussen carefully documents the evolution of Extension out of organizations and activities, such as agricultural societies and clubs, farm journals, the Morrill and Hatch Acts, boys' and girls' clubs, and later, the Progressive movement and the Country Life Commission.

Chapters 4 and 5 describe the establishment of Extension and its responses to two world wars and the Depression. Rasmussen skillfully documents the origins of Extension's orientation to three principal groups—agriculture, homemakers, and youth. He also explains its liaisons to other institutions and agencies such as the American Farm Bureau, the Agricultural Adjustment Administration, Soil Conservation Service, the Farm Credit System, the Rural Electrification Administration, and the Tennessee Valley Authority. Extension's dual roles as an educational institution and action agency are portrayed in the development of educational methodology and programs such as the Women's Land Army and Victory Farm Volunteers.

Chapters 6 through 9 contain extensive anecdotal examples of Extension's past and present programs in agriculture, home economics, 4-H, and rural and community development. While informative, these chapters suffer from the author's apparent use of Extension's own success-story reporting system, which emphasizes numbers reached, behavioral changes, and results. We learn, for example, that "in 1985 the urban gardening program was active in twenty-one cities. In addition to the federal appropriation of $3.5 million, local governments and private agencies contributed another $1 million. A staff of 171 conducted the program, with help from 2,300 volunteers. Some 186,000 participants worked an area equivalent to more than 670 acres, from which about $20 million in produce was harvested" (p. 136). By my calculations, that amounts to nearly $30,000 per acre, slightly more than $100 per person and over $4 per dollar invested!

Chapter 10, "Beginning the Next Seventy-Five Years," is even more disappointing. Those who have read the ECOP Futures Task Force Report and the outcome of ECOP's National Priority Initiative Process, "Cooperative Extension System National Initiatives: Focus on Issues" can skip the last chapter.

The book concludes with five appendices containing biosketches all of Extension Service administrators, a list of Distinguished Service Ruby Awards, a breakdown of funding from 1914 to 1988, the Smith-Lever Act of 1914 as amended through 1985, and the Memoranda of Understanding and Project Agreements between the Land-Grant Institutions and the USDA in effect in 1988. The book also contains nearly sixty photographs and illustrations.

Taking the University to the People is a fascinating and informative historical account of the Cooperative Extension Service. It should be required reading for all new Extension employees and recommended reading for all present and past employees; however, those looking for an objective analysis of the past or a blueprint for the future will be disappointed.

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Sperling, Daniel. *New Transportation Fuels: A Strategic Approach to Technological Change*. Berkeley: University of California Press, 1988, x + 532 pp., $45.

The U.S. transportation sector relies almost entirely on petroleum products and accounts for 63% of the nation's petroleum use. The U.S. Department of Energy forecasts that foreign supply will constitute 55% of total U.S. petroleum consumption by year 2000, with much of it coming from the unstable Middle East area. Thus, this sector is particularly vulnerable to supply interruptions. There also is concern that, in some twenty to forty years, we will have depleted most of the world's easily accessible high-quality petroleum. Developing new oil fields will become increasingly expensive.

Environmental concerns also are prompting efforts to find new transportation fuels that will reduce ozone, carbon dioxide, and nitrous oxide and other pollution. Most books that address alternative energy options disregard the changes necessary for the candidate fuels to become available. As a result, some options advocated are utopian and virtually impossible to achieve in a democratic society.

Sperling takes a more practical approach by developing a pathway concept of analysis that focuses on "how to generate the conditions that create and nurture" new energy sources (p. 28). He thoroughly explores the impacts and implications of technological choices. Sperling verifies that there is a transportation fuel problem.

In a section titled "Getting There From Here," Sperling identifies the barriers that restrict adoption and outlines strategies for adoption of several candidate fuels. This section is must reading for policy analysts. The final major section, "Making Choices," may startle many economists. In chapter 19, Sperling states: "The objective of this chapter is to convince the reader that conventional economic analysis and passive reliance on the market system *will not and should not* by themselves determine long-term transportation energy choices" (p. 395). Many policy makers wish to believe that a free market exists and that new products have unlimited entry to the marketplace. They choose to ignore government initiatives that tilt the playing field and distort the market. Sperling cites a number of such examples, including the Brazilian government's subsidization of its ethanol industry through credit tools, sugarcane planting, construction of conversion facilities, redesigning of motor vehicles, retooling of motor vehicle manufacturing plants, price manipulation of ethanol and gasoline, and changes in oil refining and fuel distribution. In the United States, he cites various public actions that interfere with market-oriented pricing. For example, agricultural market distortions resulting from federal commodity programs to maintain grain prices substantially higher than they otherwise would be are detrimental to the U.S. fuel ethanol industry which depends on corn for over 90% of its feedstock.

Sperling thoroughly describes the production, distribution systems, and use of both conventional and alternative fuels. The book provides a wealth of background information for the reader. He completes his book by evaluating five possible transportation energy paths: (*a*) alcohols from biomass; (*b*) petroleum-like liquids from coal, oil shale, and oil sands; (*c*) methanol from natural gas and coal; (*d*) compressed natural gas from natural gas or coal; and (*e*) hydrogen from solar energy and water. This section provides further insight into problems and potentials for the various fuels to penetrate the U.S. market.

In his conclusion, Sperling outlines the roles that government might play to ensure that the United States has adequate and dependable supplies of transportation fuels that will not degrade the environment or seriously alter our lifestyle.

Sperling's analysis of obstacles to successful development of alternative fuels is rigorous and insightful. This book is highly recommended as a text in courses on resource economics and government and public policy. The book is a gold mine of information that should be on the shelf of every public policy official.

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Articles

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Articles

Preferences of Citizens for Agricultural Policies: Evidence from a National Survey

Jayachandran N. Variyam, Jeffrey L. Jordan, and James E. Epperson

The increasing costs of agricultural programs is raising concern about the future direction of agricultural policies. Data from a nationwide survey on public attitudes toward agriculture are used to examine the structure of citizens' preferences for government involvement in agriculture and especially for policies to protect family farms. Estimates of the influence of economic and sociodemographic variables on policy preferences are computed using a multiple-indicator model. Signs and magnitudes of estimated coefficients lend support to the self-interest theory of voter behavior. Results question economic arguments suggesting altruistic motives as a cause of redistributionary agricultural policies.

Key words: family farms, linear structural relations, self-interest theory.

The rapid growth in U.S. government spending on agricultural programs in recent years has spurred the debate on the future direction of agricultural policies (Cochrane 1985, 1986; Kramer; Blandford; Freshwater). Furthermore, the federal deficit makes the U.S. Department of Agriculture's (USDA) budget a target for reduction. The recent farm crisis has, at the same time, heightened concerns about the stucture of American agriculture, focusing attention on governmental policies to alleviate stress. At issue is the viability of small and medium sized family farms and whether policies should be designed directly for their protection (Comstock, Tweeten). Proponents view the desire to preserve the family farm as a social as well as economic goal (Rausser and Irwin, p. 27; Winters, pp. 11–14). While there is difficulty in defining a family farm (Brewster; Sumner, pp. 285–86) and how to cast family farm support in a concrete and operational form (Winters), the issue remains central to policy discussions (DeLind, Comstock, Strange).

Recently, researchers have examined the agricultural policy process from a political economy perspective (e.g., Petit, Balisacan and Roumasset, Rausser and Irwin). In the political economy framework, governmental decision making is endogenized, responsive to voter and interest group preferences (Silberman and Durden, Gardner). Because agricultural policies represent significant costs to the consumers and taxpayers (OECD), the questions in this context become how far the public is willing to support the general level of transfers and whether support exists for special policies to save the family farm. Pope points to the argument that citizens may feel altruistic toward farm families and hence support income transfer to the agricultural sector. On the other hand, increasing the transparency of policy costs can lead to significant opposition from the cost bearers (Rausser and Irwin). Information on the structure of citizens' policy preferences can be useful to better understand these issues. Moreover, as Schokkaert points out, such information is a prerequisite for any normative judgment on government expenditures for the policies.

Numerous studies have examined preferences for several local national spending categories (e.g., Bergstrom, Rubinfeld, and Shapiro; Lankford; Hewitt; Schokkaert). Despite the need for such studies (Pope, p. 1101), empirical analysis of citizens' preferences for agricultural pol-

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icies are nearly nonexistent. The purpose of this paper, therefore, is to estimate the determinants of citizens' preferences for government involvement in agriculture and, specifically, for policies to protect the family farm.

Policy preferences are investigated in this study using data from a nationwide survey on public attitudes toward agriculture. Most of the previous empirical work on public preference estimation using survey data has relied on responses to a single question concerning the spending category. This approach is problematic given the measurement difficulties associated with survey data. The present study attempts to alleviate the measurement problem by modeling observed responses to multiple questions as imperfect indicators of true preferences. The underlying preferences are then related to the observable characteristics of the individuals and their environment.

Data and Variables

This study uses data from a nationwide mail survey conducted in 1986 by the S-198 Regional Research Project, "Socioeconomic Dimensions of Agricultural Change, Natural Resource Use and Agricultural Structure." The survey was intended to determine public views of changes in the structure of U.S. agriculture. The questionnaire, "Farming in American Life," was developed on a collaborative basis by members of the S-198 technical committee. Pretested questionnaires were mailed to a stratified sample of 10,000 persons representing the U.S. population. The survey contained more than 150 questions including those to determine support of farmers and farm issues, the level of knowledge of farming, and standardized questions to obtain socioeconomic background data. The random sample of persons in the United States was purchased from a national marketing firm (Donnelly Marketing, Nevada, Iowa). The population for which the sample was drawn consisted of a computer-merged list of residential telephone subscribers and automobile owners. Thus, the population should include almost all households in the United States. For example, households which do not list a telephone number and in which no member registers an automobile would be excluded, but most households with unlisted telephone numbers would be included. The sample had eight strata with oversampling in seven states. Thus, appropriate weights were assigned to the respondents to restore equal representation.[1]

To improve the return rate, the questionnaire was mailed three times with three reminder postcards. While a higher return rate would be desirable, the obtained rate was acceptable considering the fact that the sample represents the U.S. population. Including the completed, refused, and deceased questionnaires and correcting for bad addresses, the return rate was 46%. For a more detailed discussion on the development and administration of the questionnaire, data processing, and response rate, see Molnar.

Measurement of Preferences

Survey data are increasingly being used in public preference estimation (e.g., Bergstrom, Rubinfeld, and Shapiro; Gramlich and Rubinfeld; Ferris 1983, 1985; Fisher; Hewitt; Schokkaert; Husted). Other approaches include median voter models based on aggregate data (e.g., Deacon and Shapiro) and micromodels based on referendum data collected through post-referendum survey (e.g., Lankford). However, for national spending categories like agricultural support programs, surveys may be the only source of data to assess citizen preferences.

Many of the previous survey-based studies have used responses to a single preference question as the dependent variable measuring the respondent's preference for the expenditure category under consideration (e.g., Gramlich and Rubinfeld, p. 545; Ferris 1985; Hewitt; Schokkaert). Yet, survey responses are sensitive to the wording, form, and placement of questions in a questionnaire (Kalton and Schuman). Fisher, and Lewis and Cullis discussed this problem in relation to surveys on government public policy. Thus, reliance on response to one question may render the results sensitive to the formulation of the particular question. One solution is to use multiple questions that, while differing in form, wording, and context, are tied to the same underlying concept that the survey intends to measure (Kalton and Schuman).

[1] Seven states were disproportionately sampled to ensure adequate numbers for state-level analysis. The eight strata consisted of 4,000 households sampled nationwide; 1,500 households drawn from Michigan; and 750 households drawn from each of the states of Alabama, Florida, Georgia, North Carolina, Oklahoma, and South Carolina. Weights were computed to restore the proportionate representation of respondents in the strata of the national sample. For each of the eight strata, the weight was equal to the percentage each represents in the U.S. population divided by the percentage in the sample.

The present data provide responses to multiple questions concerning public preferences for government's role in protecting farmers, and especially on policies to preserve the family farm. The nine preference questions directly related to this issue and the corresponding responses are summarized in table 1. In the survey, respondents registered the intensity of their preferences on a five-category Likert scale ranging from strongly agree to strongly disagree.

Although support for farmers is the unifying concept underlying these questions, they differ in wording, focus, and context. For example, only items 4 and 5 have an explicit willingness-to-pay connotation. Items 6, 7, 8, and 9 are more general questions on the government's role in agriculture. The effect of these differences is reflected in the response pattern summarized in table 1. While only 18% of the respondents agreed with the statement that the government should not be involved in agriculture, 44% agreed with the statement that farmers should compete in a free market without government support. Further, there is a decline in the number of respondents who agree with the items on preserving the family farm when willingness-to-pay higher prices is mentioned. This is consistent with previous findings on citizens attitudes toward public expenditure which show that survey responses are sensitive to the inclusion of a "tax price" in the question (Hewitt, p. 488; Lewis and Cullis, p. 26).

Accounting for the wording and focus, the items in table 1 can be embodied in three underlying preference constructs. While the first five items measure a preference for supporting the family farm, items 4 and 5 incorporate the effect of including willingness-to-pay in the questions. To avoid confounding this effect, items 1, 2, and 3 and items 4 and 5 may be linked to two separate constructs. Items 6 to 9 focus on the government's role in agriculture and can be linked to a third construct. The first construct is called "family farm support"; the second, "family farm support with willingness-to-pay"; and the third, "government support."

The hypothesized structure relating the nine items to the three underlying constructs is verified by conducting a factor analysis of the response correlation matrix. The results from

Table 1. Summary of Responses to Preference Questions Used in Analysis

Statement	Frequency and Percent			Skewness	Kurtosis
	Agree	Undecided	Disagree		
1. The family must be preserved because it is a vital part of our heritage.	1,837 (74.6)	269 (10.9)	355 (14.4)	0.900	0.014
2. Obtaining greater efficiency in food production is more important than preserving the family farm.	647 (26.3)	516 (21.0)	1,298 (52.7)	−0.387	−0.736
3. Government should have a special policy to ensure that family farms survive.	1,405 (57.1)	467 (19.0)	589 (23.9)	0.402	−0.752
4. Most consumers would be willing to have food prices raised to help preserve the family farm.	517 (21.0)	481 (19.5)	1,463 (59.4)	−0.546	−0.465
5. Family farms should be supported even if it means higher food prices.	871 (35.4)	640 (26.0)	950 (38.6)	−0.007	−0.918
6. Government should guarantee a minimum price to farmers for their products.	999 (40.6)	497 (20.2)	966 (39.2)	−0.025	−1.074
7. The government should treat farms just like other businesses.	1,306 (53.1)	397 (16.2)	758 (30.8)	0.312	−0.962
8. Farmers should compete in a free market without government support.	1,093 (44.4)	655 (26.6)	713 (29.0)	0.137	−0.829
9. The government should not be involved in agriculture at all.	442 (18.0)	540 (21.9)	1,479 (60.1)	−0.759	−0.016

Notes: Statistics are based on 2,461 observations that were complete with respect to all variables included in the analysis. Skewness and kurtosis have been calculated based on distribution of responses in five categories labeled 1 to 5 representing strongly agree to strongly disagree. For calculation of frequencies, classes 1 and 2, and 4 and 5 have been merged to give agree and disagree, respectively. Percentages may not add up to 100 because of rounding error.

maximum likelihood factor analysis, after retaining three factors and implementing varimax rotation, are presented in table 2.[2] When the rotated factor pattern is interpreted by looking at the highest loadings of each variable, the structure revealed is identical to the hypothesized construct structure. The preference constructs thus identified are specified to depend on a vector of explanatory variables pertaining to the socioeconomic and demographic characteristics of the respondents.

Determinants of Preferences

Individuals are assumed to determine their true preferences under utility maximization over the perceived liabilities and benefits from the proposed policies (Lankford, p. 6). Because the cost-benefit perceptions vary across individuals depending upon their economic and sociodemographic characteristics, such factors should be considered simultaneously to account for the differences in preferences. In previous studies income, education, location of residence, political affiliation, sex, and age were found to be statistically significant (Ferris 1985, Hewitt, Schokkaert). The definitions and descriptive statistics of these and several additional variables considered relevant to agricultural policy preferences are reported in table 3.

Previous literature has given considerable empirical evidence that individual policy preferences reflect self-interest (Deacon and Shapiro, Fisher, Hewitt, Schokkaert). In the present case, the policies are intended to transfer income from consumers and taxpayers to agricultural producers (Gardner, Rausser and Irwin). Therefore, if individuals perceive the policies to be financed by a tax price on income, a pure self-interest model implies a negative coefficient for income. Similarly, to the extent that individuals with a higher education are likely to be better informed about the costs of agricultural support policies, the self-interest model implies a negative coefficient for education.

The private benefit variable *FMINC* (indicating whether a respondent family has income from farming) identifies the potential beneficiaries of the policies; therefore, a positive coefficient is expected for this variable. Because the five residence dummy variables generally contrast consumers against producers (farm residence is the excluded category), these variables also have a private benefit interpretation and negative signs are expected.

The variables *DARATIO* and *AGEDN* are included to capture the dependence of preferences on the degree of farm financial stress in the respondent's area and whether the respondent has been educated in the area of agriculture, respectively. Regional dummies are added, with the Midwest as the excluded category to account for differences in preference after controlling for other locational effects. Two variables are added to indicate the relatively high number of nonresponses to questions on employment status (32%) and farm income (13%). Sex and political affiliation of the respondents exert important influences, and these are discussed in relation to previous literature below. To capture the remaining socioeconomic effects, variables indicating race, religiousness, union membership, employment status, and political activity are also included.

[2] Ascertaining the number of factors to retain based on the likelihood ratio statistic poses difficulties because of the large sample size (Everitt, p. 89). Thus, while only two eigenvalues are greater than one for the response correlation matrix, a chi-square test rejects even a four-factor model as inadequate. A two-factor model resutls in items 1 to 5 and items 6 to 9 having larger loadings on factor 1 and factor 2, respectively, and thus does not separate the effect of the willingness-to-pay aspect of items 4 and 5. A four-factor model merely separates item 3 onto the fourth factor, whereas the rest of the structure is identical to the three-factor model. Thus, a three-factor model gives adequate representation of the structure underlying the responses.

Table 2. Factor Analysis Results After Varimax Rotation

Item No.[a]	Factor 1	Factor 2	Factor 3
1	0.649*	0.203	−0.116
2	−0.488*	−0.306	0.101
3	0.704*	0.164	−0.371
4	0.222	0.713*	−0.008
5	0.447	0.542*	−0.228
6	0.394	0.117	−0.506*
7	−0.114	−0.103	0.529*
8	−0.084	−0.137	0.755*
9	−0.142	0.072	0.515*
Common variance (%)	39.456	24.646	35.898

Note: Asterisk denotes the highest factor loading for the item. For clarity of presentation, the order of factor 2 and factor 3 is the reverse of the order in which they were extracted. See also footnote 2.
[a] See table 1 statements.

Econometric Method

The econometric model involving multiple indicators of unobservable variables may be formulated in the linear structural relations frame-

Table 3. Definition and Description of Variables Used in Analysis

Variable Name	Definition	Mean
Income		
INC	Midpoints of nine income categories ranging from less than $4,999 to $60,000 or more[a]	32159.3
Place of residence (excluded category: farm or ranch)		
LARCITY	1 if over 500,000 in population, 0 otherwise	0.207
MEDCITY	1 if between 50,000 to 500,000 in population, 0 otherwise	0.235
SMACITY	1 if between 10,000 to 50,000 in population, 0 otherwise	0.204
TOWN	1 if under 10,000 in population, 0 otherwise	0.172
COUNTRY	1 if outside of town not on a farm, 0 otherwise	0.131
Education (excluded category: less than high school or some high school)		
HSGRAD	1 if high school graduate, 0 otherwise	0.251
SOMECOLL	1 if had some college, 0 otherwise	0.268
COLLGRAD	1 if college graduate, 0 otherwise	0.256
POSTGRAD	1 if completed postgraduate degree, 0 otherwise	0.121
Political affiliation (excluded category: Republican)		
DEMOCRAT	1 if democrat, 0 otherwise	0.322
INDEP	1 if independent, 0 otherwise	0.406
Sex		
FEMALE	1 if female, 0 otherwise	0.313
Age		
AGE	Age in years	45.17
Agricultural education		
AGEDN	1 if took high school or college agricultural course, 0 otherwise	0.177
Farm income		
FMINC	1 if respondent's family has income from farming, 0 otherwise	0.096
FINCMISS	1 if response to farm income missing, 0 otherwise	0.128
Farm indebtedness		
DARATIO	Average farm debt-to-asset ratio in respondent's state[b]	22.489
Region (excluded category: Midwest)		
NEAST	1 if from northeast, 0 otherwise	0.203
SOUTH	1 if from south, 0 otherwise	0.317
WEST	1 if from west, 0 otherwise	0.195
Employment status (excluded category: employed full-time, part-time, or homemaker)		
UNEMPLED	1 if unemployed, 0 otherwise	0.042
RETIRED	1 if retired or disabled, 0 otherwise	0.192
STUDENT	1 if student, 0 otherwise	0.020
EMPMISS	1 if response is missing, 0 otherwise	0.322
Labor union membership		
UNION	1 if member of a labor union, 0 otherwise	0.188
Political involvement		
POLACT	1 if ever contributed or worked for a political candidate, 0 otherwise	0.392
Religiousness		
RELG	1 if attended religious services during the past year, 0 if not at all	0.723
Race (excluded category: white)		
RACE1	1 if black, 0 otherwise	0.029
RACE2	1 if other, 0 otherwise	0.049

Note: Mean is based on 2,461 complete weighted observations. The standard deviations for the continuous variables *INC*, *AGE*, and *DARATIO* are 17370.2, 15.25, and 6.956, respectively.
[a] Values for the lower and upper open-ended categories were calculated using the range between midpoints of succeeding and preceding categories, respectively.
[b] Source: U.S. Department of Agriculture, Econ. Res. Serv.

work (Joreskog and Sorbom, Everitt). Let η be an $(m \times 1)$ vector of dependent variables related to X, a $(q \times 1)$ vector of explanatory variables through the linear model,

(1) $$\eta = \Gamma \mathrm{hr}\, X + \zeta,$$

where Γ is an $(m \times q)$ coefficient matrix and ζ is an $(m \times 1)$ vector of error terms such that $E(\zeta) = 0$, $E(X\zeta') = 0$, and $E(\zeta\zeta') = \Psi$. The endogenous variables η are not observed directly. Instead they are measured indirectly by Y, a $(p \times 1)$ vector of indicator variables, through the measurement model,

(2) $$Y = \Lambda \eta + \epsilon,$$

where Λ is a $(p \times m)$ construct loadings matrix and ϵ is a $(p \times 1)$ vector of error terms with $E(\epsilon) = 0$, $E(\epsilon\eta') = 0$, $E(\epsilon\zeta') = 0$, and $E(\epsilon\epsilon') = \Theta$. The variables in Y and X are assumed to be mean centered.

The covariance structure of the above model has the form

$$(3) \qquad \Sigma = \begin{bmatrix} \Lambda \;\Gamma\; \Phi\; \Gamma'\; \Lambda' + \Lambda\; \Psi\; \Lambda' + \Theta & \Lambda\; \Gamma\; \Phi \\ \Phi\; \Gamma'\; \Lambda' & \Phi \end{bmatrix},$$

where $E(XX') = \Phi$. The assumptions of the model and the hypothesized relations between variables are specified as restrictions on the parameters in Γ, Λ, Ψ, and Θ.

Imposing the restrictions implied by the relationships between indicators and the preference constructs discussed in the previous section, Λ' has the form:

$$(4) \qquad \Lambda' = \begin{bmatrix} \lambda_{11} & \lambda_{21} & \lambda_{31} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \lambda_{42} & \lambda_{52} & 0 & 0 & 0 & 0 \\ 0 & 0 & \lambda_{33} & 0 & 0 & \lambda_{63} & \lambda_{73} & \lambda_{83} & \lambda_{93} \end{bmatrix}.$$

The indicators, except item 3, are specified to load only on one construct to achieve unidimensional measurement (Anderson and Gerbing).[3] For model identification, the scales of the constructs are fixed by the restrictions: $\lambda_{11} = \lambda_{52} = \lambda_{63} = -1$. Thus, the direction of influence of exogenous variables on the constructs can be inferred directly by examining the sign of the respective coefficient estimates. There are no restrictions in Γ. Thus, the model estimates the impact of each explanatory variable on each of the preference constructs. Except Θ_{87}, all the off-diagonal elements in Θ are assumed to be zero.[4] Correlations between the residual errors in Ψ are unrestricted to allow for the influence of additional attributes not considered in the model.

The above model is a special case of the LISREL model (Joreskog and Sorbom). In particular, the explanatory variables are assumed to be fixed, and no structural relations among η are specified. The model can be considered as a system of multiple indicator–multiple cause equations. The full information maximum likelihood estimates of the free parameters in the system can be obtained by fitting Σ to the observed variance-covariance matrix of Y and X (Joreskog and Sorbom).[5]

Empirical Results

The parameter estimates and goodness-of-fit statistics for the model are reported in tables 4 and 5.[6] A 0.05 level of statistical significance is adopted in the following discussion.

The specified measurement structure fits well, as indicated by the estimated construct loadings in table 4. All the loadings are statistically significant, and the measurement R^2 is 0.968. Several goodness-of-fit statistics for the full model are also given in table 4. A simultaneous test of all explanatory variables in the full model (*FM*) against a null model (*MO*) shows that the variables jointly have significant explanatory power ($\chi^2(MO\text{-}FM)$ with 90 degrees of freedom = 677.2). The other goodness-of-fit statistics, including the structural R^2 (0.359), root mean squared residual (0.021), and the adjusted goodness-of-fit index (0.916), also point to a good model fit.

The estimated coefficients of explanatory variables and the associated t-ratios are presented in table 5. The parameter estimates in

[3] Item 3 is specified to load on the third construct (government support) because of the reference in the item to the need for special government policy (table 1). This specification retains the meaning of the constructs and gives a better model fit. The sensitivity of parameter estimates to this specification was tested by setting $\lambda_{33} = 0$ and found to be negligible.

[4] It is difficult, a priori, to specify correlated measurement errors. *LISREL* calculates modification indices which provide a clue. In the present case, in a base line model with diagonal Θ, θ_{87} had the largest modification index. Based on the nature of items 7 and 8 (table 1) correlated measurement error seemed plausible. Thus, θ_{87} is unrestricted in the final model. Close agreement with parameter estimates in the base line model indicated that the reported results are not sensitive to this specification.

[5] Analysis is based on the correlation matrix, and therefore, the coefficient estimates can be compared across variables (Saris and Stronkhorst, p. 256). Maximum likelihood estimation and inference assumes independently and multivariate normally distributed Y given X. Univariate skewness and kurtosis within the range -1.0 to $+1.0$ (table 1) indicates maximum likelihood results would be robust in the present case (Muthen and Kaplan, p. 187; Bentler and Chou). Further, the test of multivariate normality based on Mardia's coefficient of relative multivariate kurtosis (Bentler and Chou) did not reject the null hypothesis that the variables follow a multinormal distribution.

[6] Following Babakus, Ferguson, and Joreskog, the model was reestimated using polychoric correlations. The results were similar to those reported in their simulation study. While the parameter estimates based on polychoric correlations had higher t-ratios, all the goodness-of-fit statistics showed a poorer fit. Therefore, results based on product-moment correlations are reported here.

Table 4. Estimates of Construct Loadings and Model Goodness-of-Fit Statistics

Parameter	Estimate[a]	Parameter	Estimate[a]
λ_{11}	-1.000^b	λ_{52}	-1.000^b
λ_{21}	0.852	λ_{63}	-1.000^b
	(25.669)		
λ_{31}	−0.620	λ_{73}	0.552
	(−17.933)		(17.079)
λ_{33}	−0.569	λ_{83}	0.806
	(−16.615)		(24.258)
λ_{42}	−0.653	λ_{93}	0.629
	(−21.326)		(19.700)

Number of observations = 2,461
Measurement $R^2 = 0.968$
Structural $R^2 = 0.359$
Goodness-of-fit index = 0.978
Adjusted goodness-of-fit index = 0.916
Root mean squared residual = 0.021
χ^2 for full model with 202 degrees of freedom = 1062.77
χ^2 for null model with 292 degrees of freedom = 1739.97[c]

[a] The asymptotic t-statistics are given in parentheses.
[b] Construct loading is restricted to equal −1.0 for identification.
[c] The null model is obtained by restricting all elements in Γ to zero.

columns 2, 3, and 4 represent the relative impact of explanatory variables on the preference constructs "family farm support," "family farm support with willingness-to-pay," and "government support," respectively.

Income is a significant determinant of agricultural policy preferences. The coefficients for income are significant for all three preference constructs. The negative sign indicates that as income increases, support for special policies to protect the family farm as well as government intervention in general declines. The negative coefficients for income are similar to the micro findings of Gramlich and Rubinfeld (pp. 545–47) and Husted for other redistributive spending categories.

All the residence variables have negative and statistically significant coefficients with respect to η_2. This shows that urban, town, and country dwellers have strong negative preferences for agricultural policies that may lead to higher food prices. The impact of residence variables on η_3 is not as strong but indicates more opposition to government support for agriculture coming from town and country residents. The private benefit variable *FMINC* has a positive and statistically significant coefficient on η_1. Insignificant coefficients for *FMINC* on η_2 and η_3 were unexpected. However, this may reflect the presence of residence variables which have farm or ranch as the excluded category. When the model was reestimated after dropping all residence cate-

Table 5. Coefficient Estimates of Explanatory Variables and Asymptotic t-Statistics

	Preference Construct[a]		
Variable	η_1	η_2	η_3
INC	−0.138*	−0.055*	−0.064*
	(−6.565)	(−2.329)	(−3.187)
LARCITY	−0.042	−0.187*	−0.040
	(−1.100)	(−4.358)	(−1.076)
MEDCITY	−0.059	−0.193*	−0.045
	(−1.512)	(−4.380)	(−1.194)
SMACITY	−0.007	−0.114*	−0.053
	(−0.180)	(−2.725)	(−1.469)
TOWN	−0.048	−0.173*	−0.078**
	(−1.367)	(−4.405)	(−2.315)
COUNTRY	−0.030	−0.137*	−0.069**
	(−0.913)	(−3.762)	(−2.216)
HGRAD	0.037	−0.045	−0.055**
	(1.274)	(−1.386)	(−1.978)
SOMECOLL	−0.020	−0.103*	−0.077*
	(−0.635)	(−2.981)	(−2.621)
COLLGRAD	−0.059**	−0.087*	−0.079*
	(−1.881)	(−2.453)	(−2.603)
POSTGRAD	−0.058**	−0.059**	−0.094*
	(−2.152)	(−1.941)	(−3.624)
DEMOCRAT	0.084*	0.087*	0.179*
	(3.904)	(3.605)	(8.524)
INDEP	0.063*	0.054**	0.088*
	(2.927)	(2.265)	(4.245)
FEMALE	0.090*	0.087*	0.149*
	(4.845)	(4.194)	(8.288)
AGE	0.031	0.067*	−0.084*
	(1.305)	(2.513)	(−3.639)
AGEDN	0.017	−0.003	−0.009
	(0.912)	(−0.159)	(−0.483)
FMINC	0.054*	0.005	−0.012
	(2.791)	(0.220)	(−0.625)
FINCMISS	0.018	−0.025	−0.033**
	(0.984)	(−1.246)	(−1.933)
DARATIO	−0.029	−0.023	−0.037**
	(−1.312)	(−0.949)	(−1.778)
NEAST	−0.026	−0.076*	0.059*
	(−1.034)	(−2.724)	(2.489)
SOUTH	−0.070*	−0.054**	−0.012
	(−2.869)	(−1.984)	(−0.522)
WEST	−0.041**	−0.056*	−0.068*
	(−1.935)	(−2.357)	(−3.305)
UNEMPLED	−0.002	0.018	0.036**
	(−0.111)	(0.904)	(2.141)
RETIRED	−0.058*	0.007	0.014
	(−2.432)	(0.269)	(0.594)
STUDENT	−0.036**	0.017	0.001
	(−1.994)	(0.854)	(0.084)
EMPMISS	−0.043**	−0.003	−0.000
	(−2.315)	(−0.162)	(−0.000)
UNION	0.039**	−0.022	0.057*
	(2.154)	(−1.102)	(3.318)
POLACT	0.015	0.008	−0.074*
	(0.806)	(0.387)	(−4.174)
RELG	0.026	0.022	0.013
	(1.430)	(1.084)	(0.782)
RACE1	−0.021	0.004	0.019
	(−1.177)	(0.211)	(1.097)
RACE2	−0.043*	0.010	0.051*
	(−2.432)	(0.527)	(3.004)

[a] Here, η_1, η_2, and η_3 represent unobservable preference constructs and are called "family farm support," "family farm support with willingness-to-pay," and "government support," respectively.
[b] Single and double asterisks denote significance at the 1% level and 5% level, respectively.

gories, *FMINC* exhibited a significant positive impact on η_2. The coefficient on η_3 was positive but insignificant. This may be indicative of the commodity-specific nature of government programs as well as farmers' dissatisfaction with government policies.

The coefficient estimates for almost all categories of higher education are negative and significant. Estimates on η_3 show a monotonic trend implying greater opposition to government support with increasing education. On the other hand, coefficient estimates for *AGEDN* are insignificant, indicating that no differences in preferences exist between those who had agricultural courses in high school or college compared to those who did not.

The estimated impact of *DARATIO* indicates that the degree of local farm financial stress has no significant impact on preferences for policies to protect family farms. The parameter estimate for *DARATIO* on η_3 is negative and significant and may reflect the view that government intervention itself is a source of greater financial distress. The coefficient estimates for regional dummies indicate significant differences in preferences between the Midwest and other regions. Individuals from the Northeast are likely to be most supportive of a governmental role in agriculture, while those from the West are least likely to be so. This result is similar to Fisher's finding on the regional differences in preferences for the broader category of spending on all government services. Individuals from the Northeast, South, and West are also more likely to oppose policies that may lead to higher food prices compared to those from the Midwest. The above conclusions remained unaltered when *DARATIO* and regional dummies were alternately dropped to estimate the pure impact of the other.

Because the survey did not include questions on actual or perceived tax rates, this information could not be used. However, following Hewitt, an attempt was made to include a quantity variable, namely the total government payment (*GPAY*) to the agricultural sector in the respondents' state in 1985 (USDA). Parameter estimates for *GPAY*, after dropping *DARATIO* and regional dummies, showed a significant impact only on η_2, and the effect was positive. This may indicate a positive preference for respondents from areas with a relatively large agricultural sector. This view is supported by the performance of a variable pertaining to the share of total personal income in the respondent's state from farming and agricutural services (*PAGINC*). When the coefficients for *PAGINC* were estimated after excluding *DARATIO* and regional dummies, the effect was exactly the same as that of the *GPAY*. Both *GPAY* and *PAGINC* had relatively strong correlation with each other as well as with *DARATIO* and the regional dummies. When included jointly, the parameter estimates for all these variables were unstable. Therefore, *GPAY* and *PAGINC* are not included in the final model.

Political affiliation is shown to have a significant impact on policy preferences as noted in previous studies (Fisher, Francken). The present results are comparable to the findings of Fisher (pp. 543–45) and Husted, and indicate that Democrats and Independents are more likely to favor the support policies compared to Republicans. The parameter estimates for *POLACT* indicate that politically active individuals are opposed to government intervention in agriculture.

Among socioeconomic and demographic variables, effects of sex and age are notable. The coefficient estimates for sex are positive and significant suggesting that women are considerably more in favor of saving the family farm and supporting agriculture than men. Hewitt obtained similar results for other spending categories and points out that this may be indicative of the different voting pattern observed among women. The negative impact of age on preference for government support is similar to the results of Ferris (1983) and Hewitt. As age increases there is greater disapproval of governmental role in agriculture. Yet, there is a greater approval of policies to preserve the family farm. This may arise because older people have more cultural attachment to the concept of the family farm.

Membership in a labor union has a positive impact on preference for government support as evidenced by the positive and significant coefficient for *UNION* on η_3. Further, while unemployed individuals are more likely to favor government support, other employment status variables show no significant influence on this construct. With regard to preserving the family farm, the difference in preference between union and nonunion individuals disappears when willingness-to-pay is introduced. Similarly, under willingness-to-pay, there is no difference in preference for preserving the family farm based on the employment or the racial status of individuals. While in all three cases there is no difference in preference between blacks and whites, individuals from other races exhibit positive preference for government support compared to

whites. The coefficient estimates for *RELG* are insignificant across the three preference constructs indicating that, controlling for other socioeconomic effects, religiousness is not a significant determinant of preferences. Political affiliation, political involvement, and religion are probably all endogenous. However, when the model was estimated after excluding these variables individually and jointly, there was no reversal in sign or change in inference for the coefficients of the remaining variables.

The present results are striking compared to many previous studies on public preferences in that economic, sociodemographic, and political variables are all significant with theoretically plausible signs (Fisher p. 529; Ferris 1983, 1985). The consistency and the relatively larger magnitudes of the impacts of income, education, political affiliation, and sex across the preference constructs are especially notable. By considering preferences for family farm support with and without willingness-to-pay, the model is able to reveal shifts as well as consistency in the impact of the explanatory variables in a parsimonious manner.

Concluding Comments

This study involved the use of data from a national survey of public attitudes toward agriculture to estimate the structure of citizens' preferences for policies to preserve the family farm and support agriculture. While the distribution of responses to particular survey questions indicates considerable support for the policies, the support is shown to erode when the questions are asked in a different context. Therefore, a latent variable formulation is used to control for the measurement error and estimate the impact of economic, sociodemographic, and political variables hypothesized to influence the underlying preferences.

Taken together, the results on the impact of income, education, residence, and farm income support the view that individuals act in their self-interest in deciding preferences for government policy in agriculture. These results cast doubt on the economic arguments suggesting altruistic motives of citizens as a cause of redistributionary agricultural policies. The economic variables perform as predicted by the self-interest theory even on the widely discussed issue of preserving the family farm. The results show the degree to which urban, town, and country dwellers are averse to the policies that may lead to higher food prices. The residence variables and variables indicating employment status, union membership, and race exhibit context-specific influence with regard to preferences for protecting the family farm, with their impacts sensitive to the mention of willingness-to-pay higher food prices. These results lend support to the suggestion that increasing the transparency of policy costs can spur the policy reform process.

With regard to government support, higher income, residence in town or country, higher education, higher age, residence in the West, and political activity all indicate greater opposition. The estimated impacts of sex and political affiliation indicate that women and Democrats and Independents tend to favor the support policies compared to men and Republicans, respectively.

Since the study is based on a one-time cross-sectional survey, the dynamic aspects of preferences could not be addressed. This may be important inasmuch as policy preferences could be influenced by changing economic and political events (Lewis and Cullis, p. 29). In particular, the effect of variables measuring financial distress and psychological variables indicating policy perceptions may be important and can be adequately studied only with repeated samples. The present results on the effect of financial distress must therefore be interpreted with caution. Future research on agricultural policy preferences would also benefit from information on perceived tax prices, and well-structured questions on willingness to pay.

On a final note, if a policy objective is to support the small or family farm or agriculture in general, the profile of those most likely to oppose such policies are males with high levels of income and education. Interestingly, that profile characterizes the majority of the graduates of land grant universities: males with a college education and above-average earnings. It appears that those with whom land grant universities have the most direct contact would not support policies to aid family farms, however defined. Further, the exposure to agriculture in course work at the high school or college levels had no effect on the degree of support for agricultural programs. Although only a small percentage of students at a land grant university are exposed to agriculture, the mission and the raison d'être of land grant universities may not adequately be conveyed to the student body.

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A Policy Analysis of China's Wheat Economy

Catherine Halbrendt and Conrado Gempesaw, II

This paper examines the impacts of China's historical and anticipated future reforms on its domestic wheat economy and how it affects the import demand for wheat using a stochastic coefficient regression method. The results strongly support the hypothesis that producers and consumers in the post-reform era were responsive to a less controlled economy. Furthermore, the higher import forecasts indicate that China will interact more with the world wheat market.

Key words: China, policy, stochastic coefficients, wheat.

The world wheat market is highly dependent on the trade behavior of the major centrally planned economies, such as China. During 1961 to 1987, China's wheat imports were substantial, averaging about 9.3% of total world traded volume annually (USDA). However, since 1978 China's import behavior has added significant uncertainty to the world wheat market (Ralston). China import levels reached a historical high of 13.57 million tonnes in 1980, but dropped to about 5 million tonnes in 1985 and 1986 (Carter and Zhong). The import fluctuations from 1978 to 1986 can be attributed to the new reforms since 1978, particularly the decentralization of farm household decision making and the liberalization of markets for surplus commodities. Recently, according to *Farmline,* in order for China's farm sector to keep up with the growing population and rising incomes resulting from economic reforms, China had to increase its wheat purchase in 1987 to 13.5 million tonnes. By virtue of having 25% of the world population and limited new arable land, China will continue to play a major role in the world's wheat market.

This article examines the impacts of China's historical and anticipated future reforms on its domestic wheat economy and the import demand for wheat. Specifically, this paper attempts to assess China's wheat policies before and after the reforms of 1978 and to forecast domestic wheat production, consumption, and imports. The following sections describe the model specifications, rationalize the stochastic coefficient regression approach, present the empirical results, and consider their implications.

Model Development

The China wheat model in this study consists of three components. The first component models the production relationships with separate yield and acreage response equations. The second part represents the consumption side and distinguishes between urban and rural residents' consumption behavior. The third component captures the trade relationships via an import behavioral equation. The development of the model is based on past studies on China by Tang and Stone, Noh, Yang, Ralston, and Carter and Zhong.

The China wheat model equations are specified as follows (see table 1 for variable definitions):

$$(1) \quad WHEATYLD = \beta_{10} + \beta_{11}{*}FERT\_HA + e$$

$$(2) \quad WHEAT\_HA = \beta_{20} + \beta_{21}{*}RWHTINDX + \beta_{22}{*}RRAPPRC + e$$

$$(3) \quad URBWHCON = \beta_{30} + \beta_{31}{*}[WHEATPRD + WHEATIMP] + \beta_{32}{*}RWHTINDX + e$$

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(4) $RURWHCON = \beta_{40} + \beta_{41}*WHEATPRD + \beta_{42}*RWHTINDX + e$

(5) $WHEATIMP = \beta_{50} + \beta_{51}*WHEATPRD + \beta_{52}*R\_WPRAT + \beta_{53}*FOR\_EXCH + e.$

Wheat Production

Before 1978, planned crop acreage and production quotas were mandated to ensure adequate grain supplies. The 1978 reforms continued to use quotas to ensure sufficient supplies and also adopted several new policies to stimulate higher production: (*a*) price incentives in which the quota prices for grain were increased by 20%, and the above-quota prices were set 50% above the quota prices in 1979; (*b*) increased allocation of chemical fertilizers, diesel oil, and other inputs to agricultural production (Carter and Zhong); (*c*) a restructuring of agriculture to encourage farm investment and concentration of production to capture economies of scale; (*d*) tenure on agricultural land leases was extended in 1980 from five to fifteen years and further extended in 1987 to fifty years in some areas.

As a result of the market-oriented policy, the period since the 1978 reforms was characterized by substantial increases in productivity. From 1980 to 1987, aggregate wheat production increased over 6.8% annually despite almost constant sown acreage. Sown acreage stabilized because of increasing demand on land for competing farms and nonfarm use, while wheat yields per acre increased 6.9% annually. These higher yields were attributed to increased fertilizer use, better seed varieties, and improved management efficiency. The government distributes inputs such as fertilizer at favorable input-to-output price ratios (USDA). Continued production increases at these recent rates appear unlikely because land holdings are undercapitalized, overly dispersed, and suffer from inappropriate technology and managerial forms (Calkins). The leadership since the 1978 reforms will probably rely more heavily on production targets in order to ensure adequate consumer supplies and reduce reliance on the world markets (Barker, Sinha, and Rose).

Previous grain production projection models of China used simple equations, time-series, and econometric models. Tang and Stone's model was formulated equating output index to factor productivity and weighted input indexes. The fundamental problem with Tang and Stone's model, as shown by the high differential between actual and projected values, was the arbitrary weights assigned to the input indexes and productivity factors. Noh projected China's grain production with a quadratic time trend model and an ARMA (1, 1) model. Noh's projection was systematically low when compared to the actual figures. Carter and Zhong's grain production model contained separate acreage and yield equations. Their approach used population as the key policy variable in the sown acreage response equation. Their yield equation was specified as a function of a price and a time variable that was a proxy for technology. The wheat production model in this study also has separate yield and acreage equations. The equations are specified to incorporate some of the positive aspects of the previous production models and include economic variables, such as substitute price, fertilizer application rates, institutional changes, and other factors that were not explicitly specified in the previous studies.

The major contributor to growth in agricultural productivity has been the substantial increase (67%) in the use of chemical fertilizer for grains since 1978 (Stone, Carter and Zhong). Fertilizer quality and efficiency of application have also improved significantly. Thus, the general model of China's wheat economy begins with a simple yield equation in which yield is a function of fertilizer application rate per hectare. Variable definitions and descriptive statistics are shown in table 1. The conventional hypothesis of an input's contribution to productivity implies a positive β_{11} term.

Land in wheat production remained at approximately 29 million hectares throughout the 1960–87 period. One factor which may have influenced acreage response to the 1978 reforms is the price ratio of grain to cash crops (Walker). The alternative crop for such land is rapeseed (Tuan, private communication, 1989). When grain production increased dramatically and the double-price system was established, producers could take advantage of nonmandatory deliveries of rapeseed *vis-à-vis* grain crop prices at lower procurement prices and shift land to rapeseed (Carter and Zhong). Therefore, variations in wheat plantings after the 1978 reforms are hypothesized to reflect the relative prices of wheat and rapeseed. No such relationship is hypothesized prior to 1978 because the government purchased grain at fixed prices. Thus, the wheat acreage equation can be specified as a function of real wheat and rapeseed prices with a positive sign expected for the β_{21} term and negative sign for the β_{22} term.

Table 1. Data Summary—China Wheat Economy, Selected Years

Variable	Description	1960	1978	1985	1987
FERT_HA[2]	Fertilizer use (kg/ha)[5]	30	440	655	737
FOR_EXCH[1]	Foreign exchange earnings (US $00 million)	18.6	97.5	273.6	399
RRAPPRC[4]	Real rapeseed price (yuan/tonne)		3.48	2.78	2.39
RURWHCON[3]	Rural per-capita wheat consumption (kg/year)	24.6	48.7	90.1	90.3
URBWHCON[3]	Urban per-capita wheat consumption (kg/year)	30.3	51.6	82.9	83.4
RWHTINDX[1]	Real wheat price index (base year 1950)	93.3	99.0	72.2	72.0
R_WPRAT[2]	Rice/wheat world price ratio	2.13	3.29	1.72	1.66
WHEATIMP[2]	Wheat imports (000 tonnes)	1,949	8,047	6,600	12,500
WHEATPRD[2]	Wheat production (000 tonnes)	20,960	53,840	85,810	87,000
WHEATYLD[2]	Wheat yield (kg/hectare)	782	1,845	2,937	3,007
WHEAT_HA[2]	Planted wheat acreage (000 hectares)	27,294	29,183	29,218	28,930

Sources: (1) State Statistical Bureau, People's Republic of China 1986. (2) USDA ERS *Outlook and Situation Report*. (3) Piazza. (4) Sicular. 1987 figures are from USDA ERS, various sources including unpublished ones. (5) Standard weight.

Wheat Consumption

Per-capita wheat consumption in China's rural areas has been consistently lower than per-capita grain consumption in urban areas. Such skewness in food availability is common among developing countries. Before the 1978 reforms, with negligible gains in domestic wheat production per capita, deficit years saw sharp reductions in rural per-capita consumption, and increased wheat imports were principally used to maintain urban rations (Barker, Sinha, and Rose). After the reforms, the large gains in wheat productivity have enabled rural per-capita consumption to increase dramatically, closing the gap between rural and urban consumption. Furthermore, China has allowed incomes and relative market prices to determine food consumption patterns (OECD).

Past studies dealing with grain consumption models for China have one basic limitation. As noted by Carter and Zhong, these studies (Tang and Stone, Noh) lacked a strong theoretical linkage between consumption and key economic variables such as prices and income. Based on these limitations, Carter and Zhong's rural and urban grain consumption equations were specified as a function of per capita income and lagged consumption. Lagged consumption was used to reflect the influence of consumption habits on current consumption. However, the lagged consumption variable is not used in this study for the following reasons. In Ishikawa's survey on food grain consumption, the results underscored the economic importance of the turning point of direct grain consumption as economic development improves. In the case of Taiwan, he noted that direct grain consumption peaked in 1969 and declined thereafter. China's current economic development stage is approaching, if not at, the stage achieved by Taiwan in the 1960s (Tuan, personal communication 1988; Ralston). For some fairly developed regions, direct consumption of grain has already begun to decline (Walker).

This study's wheat consumption equations include economic variables such as income, price, and separate urban and rural per-capita consumption. The equations are also formulated to use the available statistical data since the economic reform was implemented. Separate urban and rural per-capita wheat consumption equations are specified to test the effects of prices and available supply on changes in wheat consumption. Urban per-capita wheat consumption is specified as a function of available supply (domestic production plus imports) and the real price of wheat; β_{31} is hypothesized to be positive, while β_{32} is hypothesized to be negative.

Per-capita rural wheat consumption is specified as a function of wheat price and production. Instead of using the income variable as an explanatory variable, rural consumption is hypothesized to be positively related to production because rural consumption depends on the residual amount after fulfillment of the quota rather than on income. A negative relationship between rural per-capita consumption and price is anticipated.

Wheat Imports

China's grain imports (of which 85% have been wheat) have increased substantially since 1960. This is attributed in part to grain production dropping by 50 million tonnes due to perverse economic incentives and poor weather from 1958 to 1960. By 1965, grain production recovered to the pre-1958 level and continued to increase into the late 1970s. During that same period, grain imports averaged five million tonnes, due to government intervention by restricting food consumption through rationing in the urban areas and obtaining target supply through procurement quotas. However, in 1980, 13 million tonnes of wheat were imported and remained at that level until 1982. The record import levels occurred even though China was setting new production levels. According to Carter and Zhong, the large quantity of grain imports after 1978 is attributable to the reforms of 1978.

In the past, China's economic goals were aimed at production. Provincial self-sufficiency in grain was promoted regardless of economic efficiency. These types of policies proved to be self-defeating, and since 1978 major changes occurred to offset the differences between consumption and production. Producers were allowed to reallocate their resources to reflect comparative advantages and produce more profitable crops. Consumers could purchase grain on the free market. The consequences that ensued from the 1978 reforms had varying influences on wheat imports.

According to Ralston, grain import needs will also be influenced by policies encouraging production of other crops, such as cotton, sugar, and oilseeds. These crops have been more expensive to import. All these policies together influence the production of wheat. Moreover, the production quantity will be supplemented with imports to meet consumption targets.

During the 1960s world grain prices and China's terms of trade favored the export of rice and imports of relatively cheaper wheat. Wheat imports were periodically curtailed due to severe balance-of-payments problems. Record levels of domestic production in 1983 and 1984 initiated a downward trend in China's wheat imports. This downward trend has already reversed its course recently because of slower growth in domestic production and pressures from increasing population. The wheat import equation is specified as a function of foreign exchange earnings, ratio of world wheat price to world rice price, and current year's production.

Wheat imports are hypothesized to increase as foreign exchange earnings permit and to fall as world wheat prices rise relative to world rice prices. Imports are expected to be inversely correlated with the current year's domestic production.

Data Definitions and Sources

Annual time-series data covering the period 1960–87 were used to estimate the five equations discussed above. All the data except urban and rural per capita consumption, the wheat price index, the rapeseed price, and the general price index were taken from USDA, "China: Situation and Outlook Series." Rural and urban per-capita consumption data were calculated using data on per-capita cereal availability and percentages of urban and rural grain consumption (Piazza). The real wheat price index was calculated by using the purchasing price index of wheat deflated by the general price index. The rapeseed price was taken from the December 1988 issue of *China Quarterly*. Any remaining data were taken from various publications of the China's State Statistical Bureau (see footnotes, table 1).

Estimation and Forecast Method

The general objective of this study is to demonstrate whether the 1978 economic reforms influenced the structure of China's wheat economy. Conventionally, dummy variables are used in standard fixed coefficient estimating methods such as ordinary least squares (OLS) to capture policy impacts on the structure of a sector. However, some limitations are encountered when using this conventional approach. The first problem is the difficulty in defining the stages of the policy's impact, i.e., the exact timing of when the policies are announced, when they are in full effect, and how they are fine tuned. Second, the fixity of agricultural assets and inelastic supply and demand contrast with the abrupt shocks that occur when dummy variables are used. Third, a fixed coefficient estimation method assumes constancy in the marginal contribution of causal factors which is restrictive when evaluating the impacts of China's evolving policies.

Because there were no strong theoretical grounds for choosing linear specifications and gains from the economic reforms were not sys-

tematic as evidenced by the changes in the growth rates, this study chose the stochastic coefficient regression approach (SCM) developed by Swamy and Tinsley (see appendix). Other reasons for choosing the SCM approach included functional form specifications (which was stated as a source of uncertainty in Van der Gaag's study on China), aggregation effects, changes in tastes and technology, ability to accommodate changing structural parameters due to a new governmental regime, and the ability to generate time-dependent elasticities (Conway).

Another objective of this study is to forecast China's future production, consumption, and imports. Conway; and Conway, Hrubovcak, and Le Blanc conducted several studies supporting the general superiority of SCM over fixed-coefficient methods in forecasting. In this study, two measures similar to Conway's were used to test the relative forecasting efficiency of SCM over fixed-coefficient method. First, out-of-sample forecasts for the 1985–87 period from SCM and OLS models, reestimated for the 1960–84 data, were compared. Second, root mean square error (RMSE) statistics of the out-of-sample forecasts were also compared. The results in table 2 show that the SCM has much smaller root mean square errors for each of the model's equations. Table 3 shows the results of the out-of-sample forecasts. The SCM method was definitely superior because almost all of the forecasts were closer to the actual values.

Estimation Results and Discussions

Parameter estimates of this study's model are presented in table 4. Elasticities of selected variables for the 1970–87 period are shown in table 5. All parameters have the expected signs. The estimated parameter on (*FERT_HA*) of the yield equation had the expected response and the elas-

Table 2. Forecast Evaluation Statistics (Root Mean Square Error)

	Model	
Equation	Stochastic Coefficient Method	Ordinary Least Squares
Wheat yield	180	336
Wheat acreage	490	706
Rural consumption	8.1	8.5
Urban consumption	11.3	11.8
Wheat imports	4,200	6,127

Table 3. Out-of-Sample Forecasts 1985–87

	1985			1986			1987		
Dependent Variable	Actual	Stochastic Coefficient Method	Ordinary Least Squares	Actual	Stochastic Coefficient Method	Ordinary Least Squares	Actual	Stochastic Coefficient Method	Ordinary Least Squares
Wheat yield (kg/ha)	2,937	2,976	2,535	3,048	3,200	2,705	3,007	3,276	2,763
Wheat acreage (000 ha)	29,218	29,400	28,655	29,627	29,496	28,696	28,930	29,736	29,488
Rural cons. (kg/yr)	90.1	80.8	80.9	90.3	84.4	83.8	90.3	81.8	80.8
Urban cons. (kg/yr)	82.9	68.8	69.2	83.1	72.0	71.8	83.4	75.6	73.2
Wheat imports (000 tonnes)	6,600	8,541	11,326	8,500	10,751	13,912	12,500	18,060	20,311

Table 4. Wheat Equations Estimated Parameters

Dependent Variable	Independent Variable	Stochastic Coefficient Method (mean value)		Ordinary Least Squares[a]	
Wheat yield	Constant	270.97	(17.2)[b]	674.18	(11.6)
	Fertilizer application	9.77	(1.51)	3.00	(20.8)
Wheat acreage	Constant	29,249.03	(18.66)	29,319.50	(30.75)
	Wheat price (lagged)	3,968.20	(1.23)	4,449.34	(1.87)
	Rapeseed price (lagged)	−1,153.41	(−1.68)	−1,286.70	(−2.64)
Rural per capita wheat consumption	Constant	11.57	(0.31)	−46.84	(3.6)
	Wheat production	0.00081	(1.09)	0.0007	(12.4)
	Wheat price	−1.877	(−.48)	−36.02	(−3.1)
Urban per capita wheat consumption	Constant	20.98	(0.2)	−36.33	(3.61)
	Wheat supply	0.00063	(1.25)	0.0005	(14.42)
	Wheat price	−6.33	(−0.64)	−19.90	(−2.31)
Wheat imports	Constant	3,448.45	(2.79)	3,992.6	(1.44)
	Wheat production	−.104	(−2.64)	−0.120	(−2.25)
	Rice/wheat price ratio	1,016.6	(1.85)	1,174.29	(1.47)
	Foreign exchange earnings	52.54	(4.92)	45.62	(4.27)

[a] Autocorrelation problems were corrected using the Prais-Winsten method.
[b] t-statistics are in parenthesis.

ticities of yield with respect to fertilizer application through time increased from 0.7 to 0.9 (table 5). The more elastic trend is logical because fertilizer quality (as cited by Stone) improved greatly since the 1978 reforms. The elasticities of the acreage planted equation with respect to prices since 1978 were in general very inelastic. The inelastic responses could be attributed to commitments to fulfill governmental contracts, thus decreasing land base due to nonagricultural use and other more lucrative enterprises.

The rural and urban per-capita consumption equations showed the expected responses to wheat price and supply with urban consumers slightly more responsive. Elasticities of the responses of urban consumers to wheat prices became more inelastic in recent years, declining from −0.2 to −0.055 for the 1970–87 period. The post-1978 reform elasticities were slightly higher than the price elasticity (−0.005) Ito, Grant, and Wesley estimated for China's rice. This trend toward more inelastic responses of consumption to prices reflects the amount of cereal grains already in

Table 5. Estimated Elasticities of China Wheat Economy for Selected Variables and Years

Year	Yield/ Fert._ha	Acreage/ Wheat Price	Urban Consumption/ Wheat Price	Wheat Imports/ Price Ratio	Wheat Imports/ Foreign Exchange
1970	0.767		−0.200	0.675	0.316
1971	0.789		−0.200	0.705	0.479
1972	0.804		−0.156	0.451	0.334
1973	0.800		−0.170	0.518	0.553
1974	0.824		−0.155	0.540	0.618
1975	0.836		−0.146	1.015	1.761
1976	0.850		−0.136	0.556	1.124
1977	0.818		−0.152	0.292	0.474
1978	0.856	0.075	−0.121	0.412	0.623
1979	0.875	0.124	−0.108	0.278	0.829
1980	0.860	−0.033	−0.112	0.186	0.684
1981	0.875	0.221	−0.099	0.209	0.891
1982	0.891	0.278	−0.090	0.135	0.890
1983	0.905	0.016	−0.074	0.186	1.234
1984	0.914	−0.034	−0.064	0.236	1.821
1985	0.909	0.136	−0.055	0.286	2.208
1986	0.913	0.073	−0.054	0.195	1.903
1987	0.911	0.273	−0.055	0.116	1.844

the Chinese diet. Sixty percent of the Chinese diet by weight is currently comprised of wheat and rice. Based on Ishikawa's study on developing countries, this trend suggests that urban consumers could be approaching the peak consumption level of grains.

All the parameter estimates of the wheat import equation had the hypothesized signs. Foreign exchange is shown to have an impact on wheat imports. The range of elasticities between wheat imports and foreign exchange earnings was wide, ranging from 0.3 to 2.2 (see table 5). The elasticities were greater than one in the mid-1980s and generally less than one before the 1978 reforms. This trend could indicate that the Chinese planners are becoming more open to international trade and market forces.

The estimated parameter on (*R_WPRAT*) was positive suggesting that the Chinese planners have considered relative world rice and wheat prices when making import decisions. The elasticities were generally positive but inelastic. During the post-1978 reform period, the elasticities were lowest, suggesting that the planners were more responsive to consumption preference rather than maximizing foreign exchange earnings. Historically, to maximize foreign exchange earnings, China has exported expensive rice when the world price was high, disregarding domestic preference for rice (in the southern region), and substituting less expensive wheat when the world wheat prices were relatively lower. The lower elasticities indicate that Chinese planners might have been less inclined to continue these past practices.

Wheat Economy Projections

The estimated model of this study was used to project China's wheat economy performance from 1988 to 1991. In order to project yields, acreage planted, consumption, and imports, the application rates of fertilizer, domestic prices of wheat and rapeseed, foreign exchange earnings, and world prices of rice and wheat must be projected first. For comparison, two scenarios were assumed. One was based on the annual growth rates of the current regime assuming this will continue into the future; the other scenario was based on projections by Carter and Zhong, USDA, and Stone.

For the yield equation, fertilizer application rates were assumed to continue to grow at 6% annually for the current regime. According to Stone, the average application rate in China is still low compared to Japan and Korea. Roughly two-thirds of China's farmland is seriously underfertilized, especially with potassium and phosphorus; it can benefit considerably from higher application. Recently, the Chinese government reinforced the incentive system allowing farm households to buy more and better quality fertilizer at fixed prices (USDA). Based on this, the alternative scenario was based on a higher fertilizer application growth rate (8%).

For the acreage planted equation, the current regime prices for wheat and rapeseed were assumed to continue at annual rates of negative 3.4% and 4.0%, respectively. According to Carter and Zhong, the price ratio of grain to major cash crops is likely to increase slightly in the foreseeable future. Their study indicated that the actual grain price will increase about 5% annually until 1990 as more grain goes through the free market. Nominal rapeseed price rose 60 to 80 yuan per tonne in 1988 (Sincular). As such, the real wheat and rapeseed prices were assumed to grow moderately at 1.5% and 1%, respectively, in the alternative scenario. The same assumptions on wheat prices were used in the consumption equations. Because of the stronger demand for wheat on the world market in recent years, this study's current regime and alternative scenarios assumed that the ratio of rice price to wheat price will increase at the same rate versus a declining rate prior to 1987.

Foreign exchange earnings grew at an annual rate of 17% since the 1978 reforms. Based on USDA expectations, foreign trade should continue to increase but at a lesser rate. Thus, a 10% annual increase in foreign exchange earnings was assumed for the alternative scenario. To capture the recursive character of the model, the predicted values of the endogenous variables were used in other equations using those variables as explanatory factors. Projections for yield, acreage planted, consumption, and imports are shown in table 6.

The forecasts show that if China can sustain its current productivity (the current regime scenario), yield per hectare would increase 7.6% annually, while acreage planted would increase slightly. With increasing consumption predictions, imports would increase to a record high of 35 million tonnes. The alternative scenario assumed a higher fertilizer application rate which resulted in a much higher yield forecast of 8.7% annual growth. The higher productivity along with minimal change in planted acreage forecasts resulted in a much lower import forecast than the current regime's scenario.

Table 6. China's Wheat Economy Forecasts Using Stochastic Coefficient Method

	1988	1989	1990	1991
Wheat yield forecasts (kg/hectare)				
Current regime	3,294.89	3,506.63	3,701.02	3,941.51
Alternative	3,322.62	3,567.33	3,975.69	4,272.65
Wheat acreage forecasts (thousand hectares)				
Current regime	29,562.8	29,592.8	29,624.3	29,655.8
Alternative	29,558.4	29,551.3	29,539.8	29,532.7
Rural per capita wheat consumption forecasts (kg/year)				
Current regime	96.3	101.9	107.2	113.6
Alternative	96.9	103.3	113.9	121.6
Urban per capita wheat consumption forecasts (kg/year)				
Current regime	90.4	97.7	105.5	114.8
Alternative	90.2	94.5	102.5	109.1
Wheat imports forecasts (thousand tonnes)				
Current regime	17,953.1	22,669.9	28,670.6	35,752.1
Alternative	15,313.6	16,674.7	17,234.7	18,882.7

Note: Current regime scenario: the exogenous variables annual growth rates were based on the current regime's growth rates. Alternative scenario: the exogenous variables annual growth rates were based on other studies assumption/projections.

Forecasts of this study and past studies are compared in table 7. This study's yield forecasts are comparable to Carter and Zhong's of 0.73 to 0.97 tonnes per hectare. The yield forecasts seem plausible because Chinese authorities still embrace the self-reliance, self-sufficiency food policy. In 1987, China's nitrogen fertilizer imports increased 100% from the previous year, supporting the hypothesis of continued emphasis on self-sufficiency in food production (USDA). The moderately increased planted wheat acreage forecasts under the alternative scenario are consistent with USDA assumptions. The likelihood of increases in future planted wheat acreage is plausible based on statements by Chinese authorities regarding the allocation of additional resources to reclaim land (USDA).

This study's model predicts consumption to grow about 5% to 7% annually for urban and rural residents. This rate is much lower than the period since the 1978 reforms. However, it is consistent with the USDA report of declining growth rate of grain consumption due to population and feed use increases. The consumption levels predicted were comparable to Carter and Zhong's study (table 7).

Finally, the results of this study indicate that imports will increase slowly but consistently into the 1990s. The alternative scenario projections for imports were much smaller than for the current regime scenario. Up to eighteen million tonnes of imports were projected to occur in 1991. This import level, according to Carter and Zhong, was not in conflict with the government's policy toward self-sufficiency and is well within China's capability in terms of transportation and balance of payments. The increasing import levels are consistent with projections by Carter and Zhong and by Ralston (see table 7). Moreover, a USDA outlook report in June 1988 stated that coastal urban areas are likely to import sizable quantities of wheat for human consumption.

Concluding Comments

China's agricultural sector growth has had an impressive record since market and price reforms were initiated in 1978. The results of this study strongly support the hypothesis that producers and consumers in the post-reform era were responsive to a less controlled economy. Regarding imports, the Chinese authorities were shown to be responsive to world prices, although they were constrained by foreign exchange earnings. At the same time, the estimated elasticities revealed the changing responsiveness of producers, consumers, and Chinese authorities' to market signals throughout the 1970–87 period. Estimated elasticities of consumption and planted acreage to prices have become more inelastic in recent years suggesting limited flexibility to respond to alternative enterprises by producers, and the increasing preference of consumers to improve their diets with more meat protein (USDA). The trend toward more inelastic responses by Chinese plan-

Table 7. Comparison of China's Grain Forecasts, Selected Variables

Variable	Product	Study	Estimation Period	Relative Change 1987–90	Assumptions
Yield (tonnes/ha)	wheat	Carter and Zhong	1965–83	0.92	Population and growth rates are 1.1% and 6%
				0.73	Population and growth rates are 1.25% and 5%
				0.52	Population and growth rates are 1.3% and 4%
	wheat	Halbrendt and Gempesaw	1960–87	0.70	Fertilizer growth rates = 5.8%
				0.97	Fertilizer growth rates = 8.0%
Production (million tonnes)	wheat	Chinese sources	N.A.	3	Sown area decreases 2.8 million ha from 1983 levels with yield increases of 19.7%
				−1	Sown area decreases 2.9 million ha from 1983 levels with yield increases of 20%
	wheat	Halbrendt and Gempesaw	1960–87	22	See projections section for the assumptions of the yield and acreage equations
				22	See projections section for the assumptions of the yield and acreage equations
Rural consumption (kg/capita)	grain	Carter and Zhong	N.A.	17.73	Personal income growth rates = 5%
	wheat	Halbrendt and Gempesaw	1960–87	16.9	See projections section for the and assumptions
				23.6	See projections section for the assumptions
Urban consumption (kg/capita)	grain	Carter and Zhong	N.A.	16.8	Personal income growth rates = 3%
	wheat	Halbrendt and Gempesaw	1960–87	22.1	See projections section for the and assumptions
				19.1	See projections section for the assumptions
Imports (−)/exports (+) (million tonnes)	grain	Carter and Zhong	N.A.	22.8	High growth rates for price, low growth rates for population and income
				−6.7	Medium growth rates for all three variables
				−31.1	Low growth rates for price and high growth rates for population and income
	grain	Ralston	N.A.	2.6	Grain production growth rates = 2.0%; rural population growth rates = 1.1%; urban population growth rates = 1%; rural consumption growth rates = 0.5%; urban consumption growth rates = 0.5%
				−3.3	Grain production growth rates = 2.5%; rural population growth rates = 1.4%; urban population growth rates = 1%; rural consumption growth rates = 1.2%; urban consumption growth rates = 0.9%
				−9.3	Grain production growth rates = 2.9%; rural population growth rates = 1.6%; urban population growth rates = 1%; rural consumption growth rates = 1.5%; urban consumption growth rates = 1.2%

Table 7. Continued

Variable	Product	Study	Estimation Period	Relative Change 1987–90	Assumptions
	wheat	Halbrendt and Gempesaw	1960–87	−15.1	See projections section for the assumption for the import equation
				−3.7	See projection section for the assumption for the import equation

ners to the world rice over wheat price ratio suggests more attention has been given to consumer preferences rather than earning foreign exchange to subsidize industrialization. The projected import forecasts of this study are similar to Carter and Zhong's and Ralston's grain projections.

Results from this study indicate that China will interact more with the world economy through higher imports. Exporters can use this information to plan their export strategies. Finally, future agricultural policy will continue to expand the role of market forces in the Chinese economy. However, the government will not cease to play an important role in influencing production decisions to meet their planned targets (Ralston, USDA).

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Appendix

SCM Approach

Following Swamy and Tinsley, and Havenner and Swamy, the first-order variant of the generalized ARIMA stochastic coefficient regression method has the following form:

(1) $$Y_t = X_t'\beta_t$$

(2) $$\beta_t - \bar{\beta} = \psi(\beta_{t-1} - \bar{\beta}) + a_t,$$

where Y_t is the dependent variable, X_t' is a vector of explanatory variables including a unit element for the intercept term. The stochastic coefficient vector (B_t) is assumed to follow a first-order vector autoregressive process with mean vector $\bar{\beta}$. The error term a_t is assumed to be a sequence of uncorrelated vector random variables with expected mean value of zero and constant variance-covariance matrix denoted by Σ_a. The correlation matrix (ψ) is a $K \times K$ matrix of fixed but unknown correlation parameters. Because Σ_a and ψ are not known but must be estimated, the SWAMSLEY (Swamy and Tinsley) computer program provides for a data-based iteration estimation procedure in which ψ and Σ_a are initially arbitrarily chosen. Through several iterations, efficient and consistent estimates of ψ, Σ_a and β_t are derived. The mean value of the stochastic coefficients from the iteration with the lowest root mean square error is then selected.

Argentine Agricultural Policy in a Multiple-Input, Multiple-Output Framework

Lilyan E. Fulginiti and Richard K. Perrin

This study shows that government interventions in Argentine agriculture substantially reduced the growth rate of output 1940–80. A multiple product, multiple input, aggregate translog profit function is estimated. Supply elasticity estimates range from zero for linseed to 1.6 for sorghum. Estimates of intervention wedges together with the estimated structure imply that export taxes, import restrictions, and domestic taxes each in isolation could have reduced aggregate output by as much as 25%–30%. These and other interventions increased beef as a share of outputs and increased the cost shares of purchased inputs and labor at the expense of capital inputs.

Key words: agricultural production, agricultural structure, Argentina.

Argentine agricultural output grew at a rate of about 1.4% per year between 1940 and 1972 (Cavallo and Mundlak, p. 13), which is a very sluggish growth rate, given earlier rates of 1.8% for 1908–20 and 2.2%, 1920–40 (Schultz). It also is sluggish relative to growth in U.S. agricultural output of 1.9% during the same period. Adjusting for factor use, total factor productivity in Argentine agriculture grew at a rate of only 0.6% during this period, compared to 1.2% in the rest of the Argentine economy (Cavallo and Mundlak) and compared to about 1.9% in U.S. agriculture (USDA).

A number of hypotheses have been offered to explain this sluggish growth, including heavy taxation of the agricultural sector, slow technological advance, and a lack of profit motivation among the dominant large landowner class. Empirical studies by Cavallo and Mundlak, Gluck, and Reca (1974) indicate that various price and tax policies have indeed significantly affected agricultural output. The purpose of the study reported here is to provide further evidence on this issue by simultaneously considering the effect of a number of such price and tax policies on the production of seven agricultural commodities and the use of three agricultural inputs in Argentina.

The approach of the study is first to specify and estimate a multiple-input, multiple-output model of the Argentine agricultural sector, based on 1940–80 time-series data. This model is developed using applied duality theory in a manner similar to previous studies of aggregate agricultural technology by Antle; Ball (1988); Shumway; Shumway, Saez, and Gottret; and Weaver. The resulting estimates of elasticities are then used to examine the effects of price and tax policies in a comparative static framework.

The Economic Model

The producer's variable profit function may be defined as

$$(1)\quad \pi(p, r; z) \equiv \max_{xy}\{p\,y - r\,x;\ (y, x; z) \in T\},$$

where p is a vector of m output prices; r is a vector of n input prices; y is a vector of m output quantities; x is a vector of n input quantities; z is a vector of l fixed factors; and T is a closed, bounded, smooth, and strictly convex set of all feasible combinations of inputs and outputs, i.e., a production possibility set. In addition, the technology is assumed to exhibit constant returns to scale. The profit function as defined by

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(1) is assumed to be convex, linearly homogenous, and monotonic in prices. If, in addition, the variable profit function is twice continuously differentiable with respect to prices, applying Hotelling's lemma yields the system of continuously differentiable output supply and input demand functions:

$$(2)\quad \frac{\delta\pi}{\delta p_i}(p, r; z) = y_i^*(p, r; z)\ i = 1, \ldots, m$$
$$\frac{\delta\pi}{\delta r_h}(p, r; z) = -x_h^*(p, r; z)\ h = 1, \ldots, n,$$

where y_i^* and x_h^* are profit-maximizing amounts of output i and input h given prices and fixed inputs.

For this study of Argentine agriculture, a translog specification is used which, as is well known, is a flexible functional form in that it provides a local second-order approximation to any arbitrary functional form.

In general,

$$(3)\quad \tilde{\pi} = \alpha_0 + \alpha\,\tilde{d} + \frac{1}{2}\tilde{d}'\,\beta\,\tilde{d},$$

where

$$\tilde{\pi} = \ln \pi$$
$$\tilde{d} = \begin{bmatrix} \tilde{p} \\ \tilde{r} \\ \tilde{z} \end{bmatrix} = \begin{bmatrix} \ln p \\ \ln r \\ \ln z \end{bmatrix}.$$

First-order differentiation of this profit function yields a system of share equations:

$$(4)\quad M = \alpha + \beta\tilde{d},$$

where M is a column vector consisting of output shares and the negative of input shares, α is a vector, and β is a matrix of the coefficients in equation (4).

Second-order differentiation of the profit function, with some manipulation of the results, yields response elasticities [see Weaver's equation (19) for elasticities as functions of estimated parameters and estimated shares]. In the multiple-input, multiple-output case, the signs of these elasticities are not an indication of isoquant curvature because all other quantities are adjusting optimally to the price change as well.

The Hicksian measure of biases induced by technical change is used in this analysis. It is based upon marginal rates of substitution and must be measured between input pairs. Technological change is said to be Hicks x_h-saving, or x_h-neutral or x_h-using relative to x_k if

$$(5)\quad B_{hk} = \delta\left(\ln\frac{x_k^*}{x_h^*}\right) \Big/ \delta\tilde{z}\gamma \gtreqless 0,$$

where the variable $Z\gamma$ is arbitrarily designated as an index of technological change (Lau). A consistent estimator for this bias in the impact of technical change for the translog specification can be derived as

$$(6)\quad \hat{B}_{hk} = \frac{\hat{\beta}_{k\tilde{z}\gamma}}{M_k} - \frac{\hat{\beta}_{h\tilde{z}\gamma}}{M_h}.$$

Argentine Agricultural Sector Data

Parameters of the agricultural supply and factor demand structure for Argentina are estimated using the functional form described previously, with time-series data for the years 1940–80. The seven aggregate output categories examined are wheat, corn, grain sorghum, sunflower, linseed, soybeans, and beef. The three variable input categories are labor, capital, and an aggregate of fertilizers, seeds, and chemicals. Land and precipitation are considered fixed within the annual observation interval. A third fixed input variable is time in years, which represents the index of technological change. This is equivalent to specifying exponential rates of output- and input-augmenting technological change. The trend variable could be a poor proxy for technical change if the change does not occur at a constant annual rate.

The seven commodities constitute over 70% of the value of all agricultural output in Argentina when industrial commodities such as sugar, cotton, and tobacco are included, along with fruits and vegetables. However, capital share is available only for the entire agricultural sector, and the land index is a quality-adjusted index which was available only for the entire sector. Any bias introduced by these approximations is probably small because of the consistently large fraction of total agricultural resources devoted to this set of commodities. The six crops used 94% of harvested crop acreage in the first five years of the data and 89% in the last five years, while beef used about six times the amount of land devoted to crops during most of this period.

Crop production data, in millions of metric tons, were obtained from Banco de Analisis y Computacion. Average crop prices received by farmers were obtained from Bolsa de Cereales, and were converted to 1960 pesos per quintal. Beef data, cash receipts, and farm price in pesos

per kilogram, were obtained from Argentina Junta Nacional de Carnes and were also deflated to 1960 pesos, as are all other prices in the study.

Labor data consist of the number of workers in the agricultural labor force, and the average annual agricultural wage earnings including perquisites, taken from Cavallo and Mundlak (tables 25 and 26, extended to 1980 in a personal communication from Cavallo).

Expenditure on capital services is an aggregate of several categories: repairs and operation of motor vehicles and machinery, machine hire and custom work, electricity, interest on nonreal estate debt, and depreciation on motor vehicles, machinery, and equipment. These expenditure data were taken from unpublished sources at the Ministry of Agriculture (SAG) and deflated. For the price of capital services, the procedure of Cavallo and Mundlak was used to calculate the real rate of return on capital in agriculture (though our numbers differ from theirs because of different aggregates of inputs and outputs). This rate is calculated as the ratio of the value of production (net of the values of labor and "other" inputs) to the value of agricultural capital including land. (Conceptually, this is similar to Ball's 1985 measure of the rate of return but without his deduction of depreciation, capital gains, and property tax from the value of production. The Cavallo-Mundlak procedure thus overestimates the Ball rate of return by an amount that would be nearly constant from year to year.) The rate of return we calculate averages .091, ranging from a low of .042 in 1949 to a high of .148 in 1973.

Expenditures on fertilizers, chemicals, and seeds for each of the six crops were available from SAG, though not in published form. These were aggregated across crops and inputs and deflated to provide the expenditure series for "other" inputs. A Tornquist-Theil price index for fertilizers, seeds, and chemicals was constructed using unpublished SAG price data for these inputs.

The land variable is a quality-adjusted index, calculated from Cavallo-Mundlak data (updated in private communication) as follows. The current value of agricultural land is taken as the difference between the capital stock in agriculture with land included and the capital stock with land excluded. This value is divided by a price index for land which consists of the Cavallo and Mundlak land price series. Precipitation, the second fixed input, was measured as millimeters per year for a number of weather stations in the Pampas.

Estimation and Results

A stochastic structure must be assumed for the equation system (4) in order to estimate the parameters of the profit function. We assume that any deviations of the observed output supply and input demand quantities from their profit-maximizing levels are caused by random errors in optimization, and that these disturbances are additive with zero means and positive semidefinite variance-covariance matrix. This stochastic version of the share equations (4) is estimated using the seemingly unrelated regression technique of Zellner. The system was estimated with the linseed share eliminated; those coefficients are identifiable from the other parameters using the restrictions shown in table 1. The system was estimated with a single iteration because for the iterative method the likelihood function tends to be unstable with a large numbers of parameters as occurs here.[1] In addition, the absence of normality in the errors of the share equations favors the least-squares SUR approach as opposed to the maximum likelihood iterative SUR approach.

The equations were restricted to satisfy the symmetry and homogeneity conditions as shown in table 1. Table 2 presents the parameter esti-

[1] Personal communications from A. R. Gallant; see also Deaton. Their argument is as follows. With many equations and many parameters in the system to be estimated, the first-iteration parameter estimates are likely to fit one of the equations nearly perfectly. Successive iterations will quickly drive the variance-covariance matrix toward singularity, and the likelihood function turns unstable as the determinant of this matrix approaches infinity.

Table 1. Symmetry and Homogeneity Conditions Imposed

Symmetry	$\beta_{ij} = \beta_{ji};\quad \forall i,j$
	$\beta_{hk} = \beta_{kh};\quad \forall h,k$
	$\beta_{lk} = \beta_{kl};\quad \forall l,k$
Homogeneity in prices	$\sum_{i=1}^{m} \alpha_i + \sum_{k=1}^{n} \alpha_k = 1$
	$\sum_{j=1}^{m} \beta_{ij} + \sum_{k=1}^{n} \beta_{ik} = 0;\quad \forall i = 1, \ldots, m$
	$\sum_{j=1}^{m} \beta_{hj} + \sum_{k=1}^{n} \beta_{hk} = 0;\quad \forall h = 1, \ldots, n$
	$\sum_{j=1}^{m} \beta_{rj} + \sum_{k=1}^{n} \beta_{rk} = 0;\quad \forall r = 1, \ldots, l$
Homogeneity in fixed inputs	$\sum_{r=1}^{l} \beta_{ir} = 0;\quad \forall i = 1, \ldots, m$
	$\sum_{r=1}^{l} \beta_{hr} = 0;\quad \forall h = 1, \ldots, n$

Table 2. Parameter Estimates Restricted for Symmetry and Homogeneity

		Price of												
Dependent Variable	Intercept	Beef	Wheat	Corn	Sunflower	Linseed	Soybean	Sorghum	Capital	Labor	Others	Land	Rain	Time
Beef	6.432	1.165	−0.837	−0.410	−0.136	−0.099	−0.012	−0.133	0.099	0.266	0.098	0.0658	−0.0093	−0.057
	(2.51)[a]	(0.344)	(0.217)	(0.115)	(0.093)	(0.068)	(0.040)	(0.069)	(0.291)	(0.171)	(0.086)	(0.122)	(0.179)	(0.089)
Wheat	0.466		1.307	−0.477	−0.034	−0.119	0.028	−0.179	0.174	−0.034	0.171	0.208	−0.202	0.006
	(1.97)		(0.206)	(0.087)	(0.066)	(0.040)	(0.037)	(0.043)	(0.233)	(0.130)	(0.069)	(0.094)	(0.140)	(0.071)
Corn	−1.446			0.884	−0.108	−0.038	0.004	0.012	0.093	0.002	0.038	−0.015	0.297	−0.282
	(0.958)			(0.077)	(0.043)	(0.029)	(0.022)	(0.030)	(0.102)	(0.058)	(0.035)	(0.041)	(0.063)	(0.035)
Sunflower	−0.983				0.279	0.038	−0.009	0.006	−0.091	0.037	0.016	0.033	−0.045	0.012
	(0.656)				(0.044)	(0.024)	(0.015)	(0.025)	(0.074)	(0.048)	(0.024)	(0.031)	(0.046)	(0.024)
Linseed	−0.338					0.089	0.013	0.007	0.045	0.062	0.002	0.016	0.066	−0.094
	(0.366)					(0.029)	(0.010)	(0.023)	(0.037)	(0.030)	(0.014)	(0.016)	(0.022)	(0.031)
Soybean	−0.359						0.050	0.010	−0.059	−0.009	−0.017	0.021	−0.045	0.024
	(0.326)						(0.012)	(0.011)	(.036)	(0.021)	(0.013)	(0.016)	(0.023)	(0.013)
Sorghum	−0.153							0.240	−0.007	0.004	0.041	−0.046	0.030	0.016
	(0.373)							(0.034)	(0.038)	(0.033)	(0.017)	(0.018)	(0.024)	(0.014)
Capital	−1.050								−0.099	0.001	−0.155	−0.164	−0.108	0.272
	(2.967)								(0.346)	(0.192)	(0.096)	(0.140)	(0.211)	(0.104)
Labor	0.380									−0.224	−0.105	−0.095	−0.030	0.125
	(1.65)									(0.115)	(0.054)	(0.079)	(0.118)	(0.059)
Others	−1.949										−0.089	−0.024	0.046	−0.022
	(0.856)										(0.034)	(0.040)	(0.061)	(0.031)

Note: Weighted mean square error for system = 1.598 with 297 degrees of freedom.
[a] Standard errors in parentheses.

mates of the restricted model. The table contains a total of ninety-five parameters, twenty of which are significant at the 1% level, twenty-six at the 5% level, and thirty-one at the 10% level. Eight of the ten own-price coefficients are significant at the 1% level. Durbin-Watson statistics for the restricted SUR equations ranged from 1.08 to 2.25, within the 5% levels of significance for forty-one observations and thirteen regressors.

In addition to the imposed properties of symmetry and homogeneity, monotonicity and convexity are additional properties of a profit function that cannot be satisfied globally with the translog function. However, they may hold at the specific data points used in estimating the function. Monotonicity is violated if predicted output shares are negative or predicted input shares are positive. For the restricted SUR estimates, monotonicity is satisfied at the average of the data points, and at 387 of the 410 data points (18 of the 23 negative share predictions occur at data points where the observed data share is zero or less than 0.01). Convexity is violated if own-price elasticities have the wrong sign. This condition is violated by the linseed elasticity of −.08 at the average of the data points, and it is violated at 32 of the 410 data points (19 of which are linseed elasticities).

While the structure of equation (4), as shown in table 2, can be used to evaluate the effects of prices and fixed factors on the mix (shares) of outputs and inputs, elasticities must be derived to evaluate the effects on the levels of outputs and inputs. The elasticities can be obtained by differentiation of the share equations [see Weaver's 1983 equation (19) for elasticities as functions of estimated parameters and estimated shares]. Table 3 shows own-price and cross-price elasticities calculated in this manner from the table 2 parameter estimates, evaluated at the mean value of shares.

Own-price supply elasticities are between 0.7 and 1.5 except for linseed, which is slightly negative. These elasticities are larger than the 0.1–1.1 levels estimated by Weaver, by Ball, and by Shumway, Saez, and Gottret for similar commodities within the United States using similar methods. Of the twenty-one cross-supply elasticities, fifteen are positive indicating complementary relationships among the commodities. (Ball, Weaver and Antle and Aitah found all cross relationships to be complementary in their studies.) In other words, as the price for a commodity rises, new inputs are drawn into general production (note the input elasticities in response to product prices), causing an increase in the production of other products as well. Given the elasticities in table 3, the elasticity of beef supply in response to a general increase in all output prices is 1.41, compared with 1.42 for wheat; 1.49 for corn; 2.06 for sunflowers; and 0.8, 4.58, and 1.42 for linseed, soybeans, and sorghum, respectively. A general rise in product prices then, if not offset by higher input prices, would induce a relatively elastic response of aggregate output, but it would not affect all commodities equally.

Own-price input demand elasticities for capital, labor, and others are −1.94, −1.03, and −.97, respectively, again indicating a substantial degree of price responsiveness by Argentine producers. These levels are in the same range as those estimated by Ball, by Weaver, and by Antle and Aitah (all of whom used the translog), but are much higher than the −.08 to −.28 range estimated by Shumway, Saez, and Gottret, who used the normalized quadratic. The latter study showed all input cross elasticities to be positive, while the other three studies as well as this one

Table 3. Estimated Own- and Cross-Price Elasticities

Quantity of:	Price of Beef	Wheat	Corn	Sunflower	Linseed	Soybean	Sorghum	Capital	Labor	Others
Beef	1.17	0.10	0.08	0.03	0.02	0.02	−0.02	−0.95	−0.26	−0.20
Wheat	0.15	1.42	−0.15	0.10	−0.04	0.07	−0.12	−0.82	−0.53	−0.07
Corn	0.22	−0.29	1.48	−0.11	0.02	0.04	0.12	−0.82	−0.48	−0.19
Sunflower	0.22	0.58	−0.33	1.10	0.38	−0.03	0.14	−1.67	−0.23	−0.17
Linseed	0.27	−0.26	0.08	0.49	−0.08	0.15	0.16	−0.62	0.08	−0.27
Soybean	0.78	1.75	0.57	−0.14	0.54	0.66	0.42	−2.96	−0.78	−0.85
Sorghum	−0.19	−1.03	0.55	0.21	0.18	0.13	1.56	−1.11	−0.44	0.14
Capital	1.08	0.65	0.34	0.23	0.07	0.09	0.10	−1.94	−0.49	−0.13
Labor	0.63	0.89	0.43	0.07	−0.02	0.05	0.09	−1.03	−1.03	−0.07
Others	0.83	0.21	0.29	0.08	0.10	0.09	−0.05	−0.48	−0.12	−0.97

show all of them to be negative, i.e., show inputs to be gross complements. It is useful to note the elasticity of response of a single input to a general increase in all input prices: −2.55 for capital, −2.13 for labor, and −1.56 for others. A general rise in input prices, with output prices constant, would thus tend to reduce the use of capital and labor much more than other inputs.

Finally, output elasticities with respect to input prices are in general negative. The sizes of these elasticities suggest that policies affecting credit and wages will have noticeable effects on output levels as well as input use. Further, the size of input elasticities with respect to beef, wheat, and corn prices suggests that input useage is responsive to output prices and policies that affect output prices.

The effect of technical change on relative levels of input use (bias) is revealed by comparing the time trend coefficients of each input share equation after dividing it by that input share [the terms in equation (6) above]. The estimates of these adjusted share trends (using average values of shares) are −.264 for capital, −.257 for labor, and .078 for others. Thus, technical change was biased most strongly in favor of "other" inputs and most strongly against capital. Expressed in traditional terms of pair-wise biases [equation (6)], the technical change was labor saving relative to others (.335) and capital saving relative to both labor (.007) and others (.342). This ordering of biases is consistent with the induced innovations hypothesis. Average annual price increases between the first and last five-year periods of the data were 6.8% for capital, 1.1% for labor, and 0.7% for others.

Implications for the Effects of Policies

Relative stagnation of Argentine agriculture may in part result from policies that have raised the producer price of inputs and lowered the producer price of most outputs. In this section we examine the implications of the model for evaluating the impact of various government policies on the mix of outputs and inputs and on levels of production in Argentine agriculture. The relevant policies and their approximate price effects are identified first, and then the estimated coefficients are utilized to estimate their impacts.

Estimated Price Effects

In general, the effect of a policy can be described as a percentage price wedge, that is, the difference between the demand price and the supply price, expressed as a percent of the equilibrium price. We make the assumption in this study that prices are indeed exogenous to the agricultural sector. (Argentina is a small country in the world market for these commodities, and, because agriculture represents but 7%–10% of gross national product (GNP), that sector is a reasonably small user of capital, labor, and "other" inputs.) Therefore, the price wedges created by various policies can be characterized as exogenous price changes for both inputs and outputs. We consider five kinds of policies which have affected prices paid or received by farmers: export taxes, import restrictions, exchange rate controls, domestic taxes, and minimum wages.

Ad valorem export taxes on crop and livestock products have been persistent and significant over the past forty years. Cavallo and Mundlak (pp. 59–60) report an effective average export tax rate of 29% on the entire agricultural sector from 1940 through 1972. Mielke (p. 6, p. 19) reports rates for particular commodities between 1958 and 1982. Based on data reported in these sources, we estimate conservatively that ad valorem export taxes resulted in average wedges of the following sizes: 10% for beef, 15% for soybeans, and 25% for the other crops (table 4).

Imports of machinery, chemicals, and fertilizers have been restricted both by tariff and nontariff barriers, and the restrictions have not been uniformly applied. Therefore, any estimate of the average price wedge imposed must be somewhat arbitrary. We accept Cavallo and Mundlak's estimate (p. 156) that the average tariff was 37%. With infinite elasticity of supply, prices of imported goods would fall by $(1-1/1.37) =$ 26% from actual levels if the tariffs were eliminated. This is a more conservative estimate of the price wedge than suggested by Mielke (who indicates, pp. 6–7, that tariffs alone during much of this period were 60% on machinery, seeds, and fertilizer), or by Sturzenegger (whose estimates, p. 225, of the implicit tariff coefficient for 1960–80 average 1.76).

Reca (1980) and Mielke both cite a World Bank study which estimated that overvaluation of the peso averaged 38% during 1968–74. Cavallo and Mundlak assert that 20% overvaluation is a reasonable estimate for the 1939–73 period. But the more recent World Bank study by Sturzenegger puts the figure at 18% for 1960–80; this estimate is utilized in this study.

Domestic taxes considered here include the value-added tax and social security taxes on la-

Table 4. Estimated Farm Price Changes Due to Elimination of Policies

Commodity	Export Taxes	Import Restrictions	Overvalued Currency	Domestic Taxes	Minimum Wages
	Policy Set				
	(price change in %)				
Beef	10	0	18	0	0
Wheat	25	0	18	0	0
Corn	25	0	18	0	0
Sunflower	25	0	18	0	0
Linseed	25	0	18	0	0
Soybean	15	0	18	0	0
Sorghum	25	0	18	0	0
Capital	0	−26	18	−18	0
Labor	0	0	0	−13	−10
Others	0	−26	18	−18	0

bor. The value-added tax has been 18% since it was introduced in the late 1970s to replace a number of other business taxes. Because no estimates of these other taxes are available, we assume that they, too, produced an average wedge of 18% on capital and "others" in prior years. Social Security taxes have been about 40% of wages in recent years (Reca 1980, p. 13, Sturzenegger, p. 36). These taxes do not apply to producers and nonsalaried family workers, however, who constituted two-thirds of the farm labor force in 1969 (Banco de Analisis y Computacion). We estimate that their average net effect has been to insert a 13% wedge in farm labor market (one-third of the current level of the tax). Following Reca, we estimate that minimum wages have inserted a 10% wedge in the farm labor market.

Other policies which might have introduced input and output wedges are official support prices and land taxation. After considering discussions of these policies by Reca and Mielke, it is doubtful that these policies have had significant effects on these markets over the forty-year span of our data. Agricultural credit subsidies may have been important, but there is little data on which to evaluate the price-wedge equivalent impact of these policies; thus, they are excluded from the analysis. It is clear that elimination of the policies we do consider would increase output prices and decrease input prices, with grains affected more than beef (beef producers apparently have been more successful than other producers in keeping export taxes low).

Predicted Share Effects of Policies

To evaluate the effect of policy wedges on shares of inputs and outputs, we use equation (4) with the coefficients of table 2 as estimates of coefficients α and β. The change in the share vector M equals β times the change in d, with the wedge effects in table 5 being the changes in d. The predicted changes in profit shares resulting from elimination of wedges are reported in table 5. Because the profit share changes are difficult to interpret, these results also are presented in terms of revenue and cost share changes (table 6). Grains other than linseed would increase their share of output at the expense of beef. Capital would increase its share of inputs at the expense of labor and other inputs. This latter effect occurs, even though price reductions are about the same for the three inputs because of the relatively greater elasticity of capital and labor in response to all input prices as noted above.

Predicted Quantity Effects of Policies

To predict the effects on the levels of inputs and outputs, we use a simple linear elasticity model similar to (4):

$$(7) \qquad \begin{bmatrix} \delta \ln y \\ \delta \ln x \end{bmatrix} = \Sigma \begin{bmatrix} \delta \ln p \\ \delta \ln r \end{bmatrix},$$

where Σ is the 10×10 matrix of price elasticities from table 3, and the $\delta \ln p$ and $\delta \ln r$ are again the percentage price changes shown in table 4.

Two caveats are in order regarding the use of this linear elasticity model. First, the model assumes that both output and input prices are fixed. Thus, it overestimates quantity responses that would occur if output prices were to fall or input prices were to rise with expansion. Second, equation (7) is a linear approximation at a given point in price-quantity space. As such it over-

Table 5. Average Profit Shares with and without Policy Interventions

	With Interventions (observed ave.)	Without Interventions[a]
Outputs:		
Beef	1.17	0.69
Wheat	0.82	0.73
Corn	0.43	0.40
Sunflower	0.14	0.19
Linseed	0.11	0.05
Soybean	0.03	0.09
Sorghum	0.10	0.09
Inputs:		
Capital	−1.03	−0.87
Labor	−0.49	−0.31
Others	−0.28	−0.06

[a] Predicted from equation (4) and the price changes in table 5 with variables at sample mean.

Table 6. Average Revenue and Cost Shares with and without Policy Interventions

	With Interventions (observed ave.)	Without Interventions[a]
Outputs:		
Beef	0.42	0.31
Wheat	0.29	0.33
Corn	0.15	0.18
Sunflower	0.05	0.09
Linseed	0.04	0.02
Soybean	0.01	0.04
Sorghum	0.03	0.04
Inputs:		
Capital	0.57	0.70
Labor	0.27	0.25
Others	0.16	0.05

[a] Predicted from equation (4) and the price changes in table 5 with variables at sample mean.

estimates the quantity effect of price rises compared to curvilinear supply and demand functions. Despite these limitations, the linear elasticity model is useful in evaluating the relative magnitudes of the effects of various policies.

Trade-related policies (export taxes, import restrictions and currency overvaluation) have been by far the most important distortions affecting agricultural prices (table 4). Elimination of export taxes alone would have increased production from as little as about 15% for beef and linseed to 30% for wheat and corn and nearly 100% for the relatively minor crop of soybeans (table 7). The share-weighted average increase in production would be 27%. Elimination of import restrictions would have about the same overall effect on output (29%) but would have a larger impact on beef. The output effects of exchange rate devaluation would be more modest, ranging from no effect to an increase of 14% for soybeans, with a share-weighted average of 7%.

These estimates tend to corroborate the findings of the Cavallo-Mundlak study, which indicated that the combination of trade liberalization and exchange rate management would have produced increases of 30%–40% in per capita agricultural output over a twenty-year period. We find in addition that eliminating the value-added tax, social security tax, and other input taxes would increase average output by 25%, approximately the same level as for export taxes and import restrictions, with this effect being fairly uniform across commodities. Finally, the impact of eliminating minimum wages in agriculture would increase average output by only 4%.

Table 7. Estimated Quantity Changes from Elimination of Policies

	Policy Set[a]				
Commodity	Export Taxes	Import Restrictions	Overvalued Currency	Domestic Taxes	Minimum Wages
	(quantity change in %)				
Beef	17	30	5	24	3
Wheat	33	23	10	23	5
Corn	34	26	9	24	5
Sunflower	49	48	4	36	2
Linseed	15	23	−2	15	−1
Soybean	96	99	14	79	8
Sorghum	37	25	8	23	4
Weighted output	27	29	7	25	4
Capital	47	54	9	44	5
Labor	43	29	18	33	10
Others	26	38	2	28	1
Weighted input	43	44	10	38	6

[a] Predicted from equation (7) and the price changes in table 5 with variables at sample mean.

These increases in outputs are of course created by additional input use as shown in table 7. The ratio of weighted output change to weighted input change is 0.64 for each of the policy effects, a measure of the elasticity of production from variable inputs.

It is tempting to sum the effects of eliminating the various policies, which is technically correct given the linear elasticity model. However, the linear approximation errors referred to earlier would become so significant in the case of such large equilibrium displacements that little confidence could be placed on the quantitative results. The most that can be prudently concluded from this analysis is that the major policies affecting agricultural output are export taxes, import restrictions and domestic taxes, and that any one of these alone could have restricted average output by as much as 25%.

Conclusions

This study examines Argentine agriculture to determine the possible impact of price-related policies in contributing to the relatively slow rate of growth of agricultural output since 1940. The study estimates a system of seven commodity supply and three input demand equations with a translog profit function specification. The profit function approach was satisfactory with regard to statistical significance and a priori plausibility of coefficients, although it satisfied neither monotonicity nor convexity properties over the entire data set. Estimated supply elasticities were 1.2 for beef, 1.4 for wheat, 1.5 for corn, and 0 to 1.6 for the minor crops. Estimated demand elasticities were -1.9 for capital and -1.0 for both labor and "other" inputs.

The responsiveness of both variable outputs and variable inputs to prices indicates that policies affecting price can have important quantitative effects. The major sets of such policies in Argentina in terms of price effects have been export taxes at 25% (10% for beef), import restrictions at 26% for capital and "other" inputs, currency overvaluation at 18% on tradable items, minimum wages at 10%, and other domestic taxes at 15%. Using the estimated elasticities from our model in a linear elasticity comparative statics framework, the aggregate (share-weighted) output effects of eliminating these sets of policies are 27% for export taxes, 29% for import restrictions, 7% for currency overvaluation, 25% for domestic taxes, and 4% for minimum wages. The approximation errors inherent in the linear model may lead to substantial overestimates at these levels of equilibrium displacement, but the results seem to corroborate the Cavallo and Mundlak conclusion that combined trade and exchange rate policies affected output by 30%–40% over a twenty-year period. In addition, the results show that the combined policies increased the share of beef in output by eleven percentage points, at the expense of crops (other than linseed), and decreased the input share of capital by 13% in favor primarily of nonlabor variable inputs.

If export taxes, import restrictions or domestic taxes had been eliminated between the first and last decades of our study, the resulting 25%–30% increase in production would have translated to an increased annual growth rate from 1.4% to 2.2% per year over the thirty-year interval. Such a growth rate would have been comparable to earlier levels in Argentine agriculture and would have exceeded the rate of growth in U.S. agriculture during the same period. Thus, we conclude that the price effects of various sets of policies in Argentina were sufficient to explain the relatively slow rate of growth of agricultural output.

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European Community Enlargement: Impact on U.S. Corn and Soybean Exports

Tassos Haniotis

This paper utilizes the framework of an Armington model to analyze the impact of the European Community enlargement on U.S. corn and soybean exports. Results indicate that the enlargement has a significant and negative impact on U.S. corn exports to the new EC members. Increases in U.S. soybean exports are much smaller in volume terms. Declines in U.S. corn export prices outweigh the insignificant increases in U.S. soybean export prices and therefore accentuate U.S. losses. However, the U.S.–EC agreement on their enlargement dispute cut net losses of U.S. corn and soybean exports to Spain and Portugal by about a third.

Key words: Armington model, EC enlargement, U.S. farm exports.

The 1986 enlargement of the European Community (EC) to include Spain and Portugal was a positive step toward the ideal of European unity; however, it is not necessarily in harmony with U.S. agricultural interests. With declining U.S. farm exports in the 1980s, the EC enlargement complicated the already strained U.S.–EC agricultural trade relations stemming from the adverse impact of the Common Agricultural Policy (CAP) on EC imports and world markets. The enlargement brought the two sides to the brink of a trade war and, despite the agreement on compensation for U.S. losses of grain exports to Spain, the underlying causes of U.S.–EC trade conflicts are still unresolved.[1] Consequently, the future of the agricultural trade relations between the United States and the EC is surrounded by uncertainty, which is further compounded by the process of CAP reform and its interaction with the new U.S. farm policy objectives outlined in the 1985 Food Security Act (FSA).

The enlarged EC is an important market for U.S. agricultural exports because it absorbed one quarter of total U.S. agricultural exports in 1986. Two products, corn and soybeans, accounted for 78% of U.S. farm exports to the Iberian peninsula and 28% of U.S. exports to EC-10 (USDA, *Foreign Agricultural Trade*). Moreover, 45% of total U.S. soybean exports are destined to the enlarged EC. Hence, assessing the impact of the enlargement on U.S. corn and soybean exports is important both in terms of changes that were generated in trade flows to the region and in terms of the enlargement impact on U.S.–EC agricultural trade relations. Furthermore, the EC markets for corn and soybeans exemplify two extreme cases in agricultural trade—complete protection of, and free access to, a domestic market. Because of this combination, which has created significant imbalances in EC import patterns (Buchholz, Commission of the European Communities), tariff changes in corn and soybeans exported to Spain and Portugal were implemented in opposite directions. Corn exports to the region fell under the EC variable import levy regime, thus resulting in significantly higher import tariffs. On the other hand, the moderate import tariffs on soybeans were abolished be-

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[1] On 30 Jan. 1987, the U.S. and the EC settled their enlargement dispute by agreeing on a quota of low-tariff corn and sorghum imports into Spain and Portugal from non-EC suppliers (2,000 and 400,000 MT, respectively), waiving the requirement that Portugal reserve 15% of its grain market for other EC members, and reducing EC custom duties on some industrial and processed agricultural products.

cause of the zero tariff binding for EC oilseed imports.[2]

The objective of this article is to analyze the impact of the EC enlargement on U.S. exports of corn and soybeans. The model is specified in the next section, while data and the empirical estimation of the model are subsequently explained. The impact of the enlargement is then assessed by model simulations. Concluding comments are presented in the last section.

The Model

The framework of a model for differentiated products, first developed by Armington, is utilized in this study. Denote, henceforth, commodities that are differentiated by kind as "goods" (e.g., soybeans vs. corn), and goods that are differentiated by origin as "products" (e.g., Brazilian soybeans vs. U.S. soybeans). Further assume: (*a*) weak separability of the (linearly homogenous) utility function, (*b*) constant elasticity of substitution between any two products of a good in a given market, and (*c*) equality of the elasticity of substitution between any pair of products in a given market.

Then, an importing region's purchasing decision process can be treated as a two-stage process. In the first stage, expenditure allocation among n imported goods is determined by maximizing importers' utility subject to their income constraint, with resulting import demand functions of the form $X_h = X_h(P_1, P_2, \ldots, P_n, Y)$, where X_h and P_h are quantity and price indexes for good h and Y is income. In the second stage, total expenditure on each good (Y_h) is allocated among the m products of that good. This allocation is a solution to the problem of minimizing the cost of purchasing good h, with resulting import demand functions of the form $X_{hi} = X_{hi}(P_{h1}, P_{h2}, \ldots, P_{hm}, Y_h)$. Minimizing the cost of procuring the quantity index X_{hk} subject to X_h and solving for the first-order conditions yields the following import demand function, expressed in share form, for product X_{ik} imported from region i into region k (Armington, Sarris 1980):

$$(1) \qquad X_{ik}/X_k = a_{ik}^{\sigma_k}(P_{ik}/P_k)^{-\sigma_k},$$

where the subscript h of the good is dropped for notational simplicity, a_{ik} is a constant that can be interpreted as the share of the kth exporter in the ith market, σ_k is the absolute value of the elasticity of substitution between imports from different origins in region k, P_{ik} is the price of X_{ik}, and P_k is the price index over i products of X_k in region k.

In the most general form, percentage changes in the demand for X_{ik} are given by

$$(2) \qquad \tilde{X}_{ik} = \Theta_k\tilde{Y}_k + \varepsilon_{iik}\tilde{P}_{ik} + \sum_{\substack{j=1\\ j\neq i}}^{m} \varepsilon_{jik}\tilde{P}_{jk} + \sum_{\substack{g=1\\ g\neq h}}^{n} e_{gh}\tilde{P}_g,$$

where ε_{jik} is found as (Alston and Scobie):

$$(3a) \qquad \varepsilon_{ijk} = -(1 - S_{ik})\sigma_k + S_{ik}\varepsilon_k,$$

$$(3b) \qquad \varepsilon_{jik} = S_{jk}(\sigma_k + \varepsilon_k).$$

Equation (2) expresses the demand side of the model used in the present analysis. Tildes ($\tilde{\ }$) denote percentage changes ($\tilde{x} = dx/x_0$), Y_k represents total income in region k, P_g is the price of related good g in region k, and S_{ik} is the value share of imports of the product exported from region i to region k. Parameters σ_k, ε_k and Θ_k are, respectively, the elasticity of substitution, the import demand elasticity, and the income elasticity for good h, and subscript j corresponds to products of the imported good competing with product i in region k. Finally, e_{gh} is the cross-price elasticity of good h with respect to good g in region k.

Following Sarris (1983), it is assumed that export supply flows of the ith exporting region, in terms of percentage changes, are given by

$$(4) \qquad \tilde{X}_i = \beta_i\tilde{p}_i + \Phi_i\Delta t,$$

where p_i is the internal export price (excluding all export subsidies or taxes), β_i is the export supply elasticity, and Φ_i is a trend constant.

Import prices are linked to export prices by identities that have the following form:

$$(5) \qquad \tilde{P}_{ik} = E_{ik}\tilde{p}_i r_{ik} + \tilde{\tau}_{ik},$$

where E_{ik} is the price transmission elasticity, r_{ik} is the exchange rate between currencies of regions i and k, and τ_{ik} is an exogenous shifter through which changes in policy variables, such as tariff changes, can be introduced into the model. Finally, the model is closed by the following clearing condition that restricts export

[2] The Dillon round of GATT negotiations (1960–61) resulted in the zero tariff binding for oilseeds, oilseed products, and certain nongrain feedstuffs imported into the EC (Hathaway).

supply from region i to equal the summation, across all regions k, of import demand from region i:

$$(6) \qquad 0 = \tilde{X}_i - \sum_{k=1}^{m} H_{ik}\tilde{X}_{ik}.$$

H_{ik} is the base period quantity share of exports from the ith exporting region to the kth market. Equations (2), (4), (5), and (6) form a system of N equations, where $N = 2m^2 + 2m$. The system yields percentage changes in its endogenous variables that result from exogenous variable changes. Trade policy changes and their impact on trade flows can be evaluated by varying the value of the $\bar{\tau}_{ik}$ parameters, while different assumptions concerning the exogenously determined variables ($\tilde{Y}_k$, Φ_i) could shed light into their importance in determining trade flows.

Data and Empirical Estimation

Because this analysis focuses on U.S. exports into the EC and its new members, the world is divided into five regions: the United States, (US); the European Community-10 (EC); Spain and Portugal (SP); other major exporters (OE)—Argentina, South Africa, and Thailand for corn, Brazil and Argentina for soybeans; and the residual Rest of the World (RW). Data were obtained from the European Community *Analytical Tables of Foreign Trade*, the United Nations *Commodity Trade Statistics*, and USDA supply utilization tables. Prices are per unit values, in real terms.[3] In order to adjust all prices for exchange rate fluctuations, effective consumer price indexes were constructed from data of the *International Financial Statistics* of the International Monetary Fund. Average trade shares (S_{ik}, H_{ik}) for corn and soybeans, in volume terms for exports and value terms for imports, were computed from trade flow matrices constructed for the 1983–85 period (Haniotis). This period was selected as representative for pre-enlargement trade flows into Spain and Portugal.

First-stage import demand equations were estimated using time-series annual data for the 1966–85 period and were specified as

$$(7) \qquad \ln M = b_0 + b_1 \ln PC + b_2 \ln PS + b_3 \ln Y + b_4 \ln S + b_5 T + b_6 D,$$

where M is the quantity of imports for soybeans or corn; PC and PS are import prices of corn and soybeans, respectively; Y and S represent real income and domestic supply in the importing region; T is time, and D is a dummy variable for the period after the first EC enlargement.[4] Because of the log-linear form of the import demand equations, estimated coefficients are the elasticities of the corresponding variables.

Results of the estimated first-stage import demand equations for EC, SP, and RW are reported in tables 1 and 2. Import demand for corn is inelastic in all three importing regions, while the soybean import demand elasticity exceeds unity only in SP. Own-price elasticities of import demand were statistically significant at the .05 level or higher in five of the six estimated equations (the exception being the RW corn import elasticity). Income elasticities were generally higher than one and statistically significant in all cases. On the other hand, cross-price elasticities were characterized by low values and high standard errors in all cases. Signs of all estimated parameters were as expected.[5]

The elasticities of substitution, σ_k, were estimated from equation (1) by transforming it into a logarithmic form and then pooling cross-section, time-series data of exports from all origins into an importing region (Figueroa). Since the assumption of product differentiation implies that the elasticity of substitution should not be constant among all pairs of products within a market, it has been suggested that the CRESH (constant-ratio elasticity of substitution and homothetic) function (Hanoch) is more consistent than the CES (constant elasticity of substitution) function in a differentiated products model (Deppler, Lopez). In this study, however, the use of the CES function appears appropriate because the selection of exporting regions is based on the fact that, for the period for which estimates σ_k were obtained (1974–85), corn and soybean exports to EC and SP were originating mainly from two regions, the US and OE, and a single pair of products within a market was relevant.

Estimated second-stage import demand equa-

[3] Exceptions are the EC threshold price for corn, which was adjusted on a calendar year basis and used as the import price in the estimated EC import demand equation for corn, and the U.S. export prices for corn and soybeans (FOB Gulf ports), which were used in the estimation of the corresponding U.S. export supply elasticities.

[4] The price of soybean oil (PSO) was included in the estimated equation for EC soybean imports.

[5] Alternative specifications of the first-stage import demand equations, attempting to explore cross-price effects with other products, did not yield satisfactory results.

Table 1. Estimated Import Demand Equations for Corn

First-Stage

EC: $$\ln MC = \underset{(7.939)}{4.971} - \underset{(0.421)}{0.804\ln PC} + \underset{(0.110)}{0.160\ln PS} - \underset{(0.313)}{0.478\ln DS} + \underset{(1.619)}{2.802\ln Y} + \underset{(0.161)}{0.367D} - \underset{(0.152)}{0.157T}, \qquad \bar{R}^2 = 0.861$$

SP: $$\ln MC = \underset{(3.999)}{4.719} - \underset{(0.202)}{0.421\ln PC} - \underset{(0.246)}{0.535\ln DS} + \underset{(0.736)}{1.480\ln Y} + \underset{(0.031)}{0.007T}, \qquad \bar{R}^2 = 0.879$$

RW: $$\ln MC = \underset{(0.531)}{-0.404} - \underset{(0.388)}{0.453\ln PC} + \underset{(0.451)}{0.570\ln PS} - \underset{(0.771)}{0.688DS} + \underset{(0.976)}{3.334\ln Y} + \underset{(0.186)}{0.173T}, \qquad \bar{R}^2 = 0.882$$

Second-Stage

EC: $$\ln(X_{ik}/X_k) = \underset{(0.154)}{-3.451} + \underset{(0.192)}{3.354D_1} + \underset{(0.195)}{1.141D_2} - \underset{(0.708)}{1.587\ln(P_{ik}/P_k)}, \qquad \bar{R}^2 = 0.929$$

SP: $$\ln(X_{ik}/X_k) = \underset{(0.280)}{-4.112} + \underset{(0.402)}{3.713D_1} + \underset{(0.389)}{1.040D_2} - \underset{(1.953)}{6.431\ln(P_{ik}/P_k)}, \qquad \bar{R}^2 = 0.893$$

Note: Numbers in parentheses are standard errors.

tions also appear in tables 1 and 2. EC and SP elasticities of substitution are the coefficients of the P_{ik}/P_k terms of the estimated equations, while D_1 and D_2 are intercept shifters for US and OE exports, respectively. Three out of four estimates are statistically significant at the .05 level or higher, while the t value of the fourth is relatively high. The higher value of the SP estimates reflects greater fluctuations in SP than in EC import origin during the last decade. Since estimates for RW could not be derived, the elasticity of substitution of the region was arbitrarily assumed. This assumption does not affect the overall level of imports to a region; however, it does affect the origin of imports. In turn, this could affect simulation results of the RW exports to EC and SP. But, because the share of RW exports to EC or SP is small (ranging from 1.3% for SP corn imports to 15% for SP soybean imports), the potentially negative impact on model simulations is minimal.

Export supply elasticities were derived from simultaneously estimating the demand for and supply of exports of a region by using the methodology proposed by Goldstein and Khan. In structural form, the estimated system is given by

$$\text{(8a)} \qquad \ln X_t = c_0 + c_1\ln(PX/PXW)_t + c_2\ln YW_t + c_3\ln X_{t-1},$$

$$\text{(8b)} \qquad \ln PX_t = d_0 + d_1\ln X_t + d_2\ln P_t + d_3\ln Y_t + d_4\ln PX_{t-1},$$

where X and PX are quantity and price indexes of exports, PXW and YW are trade weighted in-

Table 2. Estimated Import Demand Equations for Soybeans

First-Stage

EC: $$\ln MS = \underset{(5.405)}{-11.188} - \underset{(0.251)}{0.666\ln PS} + \underset{(0.134)}{0.314\ln PSO} + \underset{(0.389)}{0.525\ln PC} + \underset{(0.792)}{3.936\ln Y} + \underset{(0.112)}{0.389D} - \underset{(0.014)}{0.047T}, \qquad \bar{R}^2 = 0.980$$

SP: $$\ln MS = \underset{(2.566)}{-2.186} - \underset{(0.294)}{1.200\ln PS} + \underset{(0.284)}{0.491\ln PC} + \underset{(0.672)}{2.006\ln Y} - \underset{(0.262)}{0.630T}, \qquad \bar{R}^2 = 0.947$$

RW: $$\ln MS = \underset{(2.249)}{13.524} - \underset{(0.257)}{0.596\ln PS} + \underset{(0.120)}{0.175\ln PC} - \underset{(0.132)}{0.776DS} + \underset{(0.325)}{1.038\ln Y} + \underset{(0.061)}{0.265T}, \qquad \bar{R}^2 = 0.985$$

Second-Stage

EC: $$\ln(X_{ik}/X_k) = \underset{(0.073)}{-3.637} + \underset{(0.100)}{3.225D_1} + \underset{(0.118)}{2.448D_2} - \underset{(1.114)}{2.783\ln(P_{ik}/P_k)}, \qquad \bar{R}^2 = 0.973$$

SP: $$\ln(X_{ik}/X_k) = \underset{(0.223)}{-2.993} + \underset{(0.322)}{2.649D_1} + \underset{(0.321)}{1.336D_2} - \underset{(2.843)}{4.800\ln(P_{ik}/P_k)}, \qquad \bar{R}^2 = 0.670$$

Note: Numbers in parentheses are standard errors.

dexes of the world export price and the importers' real income, P is the domestic price index, and Y is an index of domestic supply, equal to production plus stocks (Haniotis, Baffes, and Ames). Export supply elasticities were recovered from the estimated structural equations as $\beta_i = (1 - d_4)/d_1$. The estimated systems of (8a) and (8b) for the US and OE are reported in table 3. Elasticities of export supply for the United States are 1.11 for corn and 0.29 for soybeans, while for OE the respective elasticities are 1.46 and 2.84. The elasticity of export supply for the EC was assumed to equal its domestic supply price elasticity.[6]

Changes in policy variables implied by the enlargement were simulated by changing the value of $\bar{\tau}_{ik}$ parameters that correspond to the price differential between the export price in the ith exporting region and the import price in the kth importing region. Post-enlargement tariff changes for SP were estimated by weighting corn or soybean tariff changes by the import market share of Spain and Portugal.[7] Finally, price transmission elasticity values (E_{ik}), except for the EC price transmission for corn (whose value was assumed), were obtained from Meyers, Devadoss, and Helmar. In summary, elasticities used in the model simulations are presented in table 4.

Simulation Results

A comparative statics approach was adopted, and the model was simulated in order to compare SP imports of corn and soybeans under the impact of the enlargement to actual trade flows for the base period 1983–85. In order to isolate the impact of the enlargement from the effect of other factors, export and income growth trends were assumed to equal zero. Two sets of scenarios were simulated. First, simulations were performed under the alternative assumptions of incorporating (A) or ignoring (B) the terms of the U.S.–EC agreement on the enlargement dispute. The agreement effect was simulated by assuming that the agreed quota of 2,000 metric tonnes (MT) of corn from all origins would be imported without any changes in tariffs. It was then assumed that the variable import levy would be imposed on corn imports whose volume would equal the difference between a projected pre-enlargement total for SP imports and the amount covered by the quota. Averages for 1983–85 were used for the variable import levy calculation.

Second, simulations were performed by assuming SP elasticity values (ε, e, σ, E) equal to those estimated for the region, which implies the continuation of the pre-enlargement import behavior of the new EC members (a). Alternatively, assuming SP post-enlargement elasticities equal to the estimated EC elasticities implies complete adjustment of the new EC members to the EC import behavior patterns (b).

Results of the model simulations, expressed in terms of percentage changes in trade flows, are reported in table 5. The following general conclusions can be derived from these results. First, the U.S.–EC agreement does have a positive impact for the United States. In both simulated scenarios, decreases in the volume of U.S. corn exports to SP and in total SP corn imports under the agreement assumption (A) are smaller than corresponding decreases under the non-agreement assumption (B). Under the assumption of pre-enlargement SP elasticities (a), the decline in U.S. corn exports to SP is 14% under (A) and 21% under (B), while under the post-enlargement assumption on SP elasticities, relative figures are 24% to 37%, respectively. Similar results apply for total SP corn imports, and for OE exports to SP, while the better performance of RW corn exports is insignificant given that its share of SP corn imports is only 1.3%.

Second, the above results indicate that the negative impact of the enlargement on SP corn imports increases by roughly a third under the assumption that SP import behavior adjusts to EC import patterns (a realistic assumption in view of ongoing adjustments in SP agriculture). Third, the positive impact of the enlargement on SP soybean imports is small under assumption (a), around 3%. However, if post-enlargement elasticities for SP are used (b), then the negative impact of the enlargement on SP corn imports

[6] The extensive use of export restitutions for EC corn exports makes the estimation of an export supply for EC corn nearly impossible. Based on 1966–85 data, the estimated equation of the EC corn supply is

$$\begin{aligned}\ln C = \underset{(2.400)}{7.098} + \underset{(0.522)}{0.880}\ln PC - \underset{(0.113)}{0.266}\ln ST \\ + \underset{(0.094)}{0.126}D + \underset{(0.071)}{0.273}T,\ \bar{R}^2 = 0.875,\end{aligned}$$

where C and ST are the EC production and stocks of corn, PC is the EC real intervention price, D is a dummy variable taking a value of one for the period before the first EC enlargement (1973), and T is time. Use of the domestic EC supply elasticity for corn was considered more appropriate than assuming a perfectly inelastic EC supply response because the analysis focused on post-enlargement SP trade flows.

[7] The weighted average increase in SP corn tariffs was 45%, while for soybeans the corresponding figure was −3%. Pre-enlargement SP import tariffs are found in Friend, Schwartz, and Newman.

Table 3. Estimated Systems of Export Demand and Supply

United States

Corn

$$\ln X_t = \underset{(1.379)}{0.236} - \underset{(0.564)}{0.197}\ln PXW_t + \underset{(0.548)}{0.358}\ln YW_t + \underset{(0.286)}{0.664}\ln X_{t-1}$$

$$\ln PX_t = \underset{(0.664)}{1.879} + \underset{(0.126)}{0.495}\ln X_t - \underset{(0.179)}{0.431}\ln Y_t + \underset{(0.164)}{0.199}\ln P_t + \underset{(0.181)}{0.451}\ln PX_{t-1}$$

System $R^2 = 0.941$, $\chi^2 = 53.858$,

Soybeans

$$\ln X_t = \underset{(0.504)}{-0.435} - \underset{(0.242)}{0.356}\ln PXW_t + \underset{(0.326)}{0.826}\ln YW_t + \underset{(0.259)}{0.279}\ln X_{t-1}$$

$$\ln PX_t = \underset{(1.133)}{2.573} + \underset{(0.523)}{1.676}\ln X_t - \underset{(0.717)}{1.689}\ln Y_t - \underset{(0.238)}{0.164}\ln P_t + \underset{(0.191)}{0.521}\ln PX_{t-1}$$

System $R^2 = 0.979$, $\chi^2 = 73.087$

Other Exporters

Corn

$$\ln X_t = \underset{(0.884)}{1.680} - \underset{(0.840)}{0.710}\ln PXW_t + \underset{(0.257)}{0.859}\ln YW_t - \underset{(0.276)}{0.240}\ln X_{t-1}$$

$$\ln PX_t = \underset{(2.549)}{-0.174} + \underset{(1.560)}{0.275}\ln X_t - \underset{(0.114)}{0.017}\ln Y_t + \underset{(1.943)}{0.381}\ln P_t + \underset{(0.200)}{0.599}\ln PX_{t-1}$$

System $R^2 = 0.925$, $\chi^2 = 49.273$

Soybeans

$$\ln X_t = \underset{(2.375)}{-2.232} - \underset{(0.272)}{0.141}\ln PXW_t + \underset{(0.683)}{1.130}\ln YW_t + \underset{(0.176)}{0.528}\ln X_{t-1}$$

$$\ln PX_t = \underset{(1.172)}{1.294} + \underset{(0.287)}{0.314}\ln X_t - \underset{(0.158)}{0.100}\ln Y_t + \underset{(0.280)}{0.345}\ln P_t + \underset{(0.266)}{0.107}\ln PX_{t-1}$$

System $R^2 = 0.969$, $\chi^2 = 52.180$

Note: Estimated systems are based on 1966–85 data. Standard errors are in parentheses.

is accompanied by a significant, positive effect on SP soybean imports. Under (*Ab*), U.S. soybean exports increase by 6.5%, while the increase is 9% in the scenario assuming that no U.S.–EC agreement had been reached (*Bb*). Finally, the impact of the enlargement on total U.S. corn exports ranges from −1% to −3%, while the impact on U.S. soybean exports is 0.5%.

Based on the above results, it is easy to compute, in volume terms, the enlargement impacts on annual trade flows, and to compare them to average 1983–85 trade flows. Under assumption (*A*), the decline in U.S. corn exports ranges from 469,000 MT (scenario *Aa*) to 828,000 MT (scenario *Ab*). As expected, corresponding decreases under (*B*) are greater, and range from 752,000 MT (*Ba*) to 1.3 million MT (*Bb*). Increases in U.S. soybean exports under assumption (*A*) range from 81,000 MT to 150,000 MT (scenarios *Ab* and *Aa*, respectively), while the no-agreement assumption (*B*) results in increases between 81,000 and 154,000 MT (again under scenarios *Bb* and *Ba*, respectively). Taking the realistic assumption that post-enlargement SP elasticities are equal to average EC elasticities, results indicate that the U.S.-EC agreement, ceteris paribus, decreased U.S. losses of corn exports to SP by one-third, or by over 400,000 MT.

Table 6 summarizes the economic value of gains and losses in U.S. corn and soybean exports to SP under all simulated scenarios. Changes in the value of U.S. exports were computed by using the simulation results and price changes generated from model simulations (changes in export prices for U.S. corn and soybeans are reported in table 5). As expected, corn prices decline and soybean prices increase under the impact of changes in trade flows resulting from the enlargement.

Because of the greater impact of the enlargement on SP corn imports, changes in U.S. ex-

Table 4. Elasticity Values Used in Model Simulations

Elasticity	US	EC	SP	OE	RW
Corn					
ε_k		−0.80	−0.42		−0.45
e_k		0.16			0.57
σ_k		1.59	6.43		2.50
β_i	1.11	0.88		1.46	1.00
E_{ik}		0.25	0.75		0.50
Soybeans					
ε_k		−0.67	−1.20		−0.60
e_k		0.53	0.49		0.18
σ_k		2.78	4.80		2.50
β_i	0.29			2.84	1.00
E_{ik}		0.90	0.85		0.50

Note: ε_k is the own-price elasticity of import demand, e_k is the cross-price import demand elasticity between corn and soybeans, σ_k is the elasticity of substitution, β_i is the export elasticity, and E_{ik} is the price transmission elasticity.

port prices for corn are greater than changes in U.S. export prices for soybeans, and the negative impact of the SP accession on the value of U.S. exports is accentuated. Under assumption (*A*), net losses of U.S. corn and soybeans range between 53 and 88 million U.S. dollars. Under assumption (*B*), net U.S.losses range between $93 million and $144 million. In the most realistic scenario, that assuming the U.S.–EC agreement and the adjustment of SP import behavior to EC patterns, the impact of the enlargement on U.S. corn and soybean exports is a net loss of $88 million or 7% of the average annual value of respective U.S. exports in the pre-enlargement 1983–85 period.[8]

Concluding Comments

This paper utilized the framework of an Armington model to analyze the impact of the European Community enlargement on U.S. corn and soybean exports. Simulating the enlargement impact under alternative assumptions concerning import elasticities of Spain and Portugal resulted in the following conclusions. First, the EC enlargement has a significant and negative impact on U.S. corn exports to the new EC members. However, the U.S.–EC agreement for compensation of U.S. losses of grain exports to Spain and Portugal limited the damage to U.S.

[8] The lack of data on SP imports of non-grain substitutes (whose level was very low before the enlargement) did not allow an assessment of their post-enlargement trade flows. However, significant increases in SP imports for such products recently indicate potential gains for U.S. exports, thus altering the net enlargement impact.

Table 5. Simulated Impact of the EC Enlargement on SP Imports and U.S. Exports and Export Prices of Corn and Soybeans

	Base	A		B	
Scenarios	(1983–85)	*a*	*b*	*a*	*b*
		(percentage changes)			
Impact on SP corn imports					
from US	3,445	−13.73	−24.10	−20.55	−36.59
from OE	2,373	−14.71	−24.80	−22.03	−37.66
from RW	558	−10.16	−20.86	−15.11	−31.65
total	6,376	−13.58	−23.84	−20.74	−36.24
Impact on SP soybean imports					
from US	4,334	3.47	6.55	3.53	9.07
from OE	1,004	3.96	7.12	3.95	9.85
from RW	157	1.37	3.35	1.37	4.64
total	5,495	3.24	6.16	3.28	8.54
Impact on U.S. exports					
of corn	42,256	−1.11	−1.96	−1.78	−2.98
of soybeans	20,233	0.74	0.40	0.76	0.40
Impact on U.S. export prices					
of corn	129	−1.02	−1.79	−1.53	−2.72
of soybeans	327	0.29	0.56	0.25	0.22

Notes: Annual percentage changes are based on average 1983–85 trade flows. Base quantities are expressed in 1,000 MT and base prices in $/MT. Scenarios: (*A*) with U.S.–EC agreement, (*B*) without U.S.–EC agreement, (*a*) pre-enlargement SP elasticities, (*b*) post-enlargement SP elasticities.

Table 6. Enlargement Impact on Annual U.S. Corn and Soybean Exports to Spain and Portugal (change in million U.S. dollars)

	A		*B*	
Scenario	*a*	*b*	*a*	*b*
Corn exports	−80	−140	−120	−211
Soybean exports	27	52	27	67
Net loss	−53	−88	−93	−144

Note: Scenarios: (*A*) with U.S.–EC agreement, (*B*) without U.S.–EC agreement, (*a*) pre-enlargement SP elasticities, (*b*) post-enlargement SP elasticities.

exports. On the other hand, increases in U.S. soybean exports resulting from the adjustments of SP to the EC zero tariff binding for oilseeds, are much smaller in volume terms.

Second, under the impact of the enlargement, declines in U.S. corn export prices outweigh the insignificant increases in U.S. soybean export prices, and therefore accentuate U.S. losses. *Ceteris paribus,* net losses of U.S. corn and soybean exports to SP are 88 million dollars, or 7% of the pre-enlargement value of U.S. corn and soybean exports to Spain and Portugal. Without the U.S.–EC agreement, these losses would be two-thirds higher in value terms, or 11% of pre-enlargement U.S. exports.

Third, the limited scope of the present analysis does not allow for an evaluation of the structural changes that are expected to occur in the new EC members, and the resulting effects on their import behavior. Nevertheless, the study indicates an important policy implication. In the past, the combination of a protectionist EC grain regime with the free entry of oilseeds in the Community distorted trade flows in a contradictory way by positively affecting U.S. oilseed exports while hurting U.S. grain exports. By generating similar trends, the enlargement has created another source of trade distortion and the potential for further U.S.–EC agricultural trade frictions.

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An Adjustment-Cost Rationalization of Asset Fixity Theory

Shih-Hsun Hsu and Ching-Cheng Chang

This article integrates a classic concept in production economics (G. L. Johnson's asset fixity theory) with the dynamic adjustment cost model. Until now the literature has considered these two to be incompatible. By relaxing the smoothness assumption of the adjustment cost function at the origin, the theory of costs of adjustment can provide a rigorous endogenization of asset fixity. G. L. Johnson and Edwards' results are then obtained when the linearity assumption of the adjustment cost function is imposed. The work reported here also indicates that both smoothness at the origin and symmetry of adjustment cost function should be subject to empirical tests.

Key words: asset fixity trap, asset quasi-fixity, asymmetric adjustment cost, discontinuity, Kuhn-Tucker theorem.

The theory of asset fixity (hereafter AFT) was spearheaded by G. L. Johnson (1956) and then developed by Edwards (1959), Hathaway, and Johnson and Quance during the last decade. It has been frequently used to explain the stylized fact of nonreversible supply response in agricultural production. Furthermore, it has also been used in examining why and to what extent assets are fixed in agriculture. G. L. Johnson claims that all the previous analyses either fail to address the depression-prosperity comparison (e.g., the "treadmill theory" by Schultz and Cochrane that focuses only on the prosperous phase of agricultural production) or lack a complete microeconomic basis to build the linkages between asset fixity and nonreversible supply. To handle adequately the impacts of asset fixity on output supply, a generalized version of the neoclassical marginal evaluation principle of the pricing of fixed factors is required.

According to G. L. Johnson (1956), an asset is fixed when its marginal value product in its present on-farm use neither justifies the acquisition of more of it nor its disposition. The bigger the gap between the acquisition cost and salvage value of that resource, the more fixity it possesses.[1] As the factor use is closely related to product supply functions, the linkage between asset fixity and supply response can then be derived from the following hypotheses: When the marginal value in use on the farm is greater than the acquisition cost, it pays to expand (invest). Likewise, if the salvage value exceeds the marginal on-farm value, the farm will contract (disinvest). More often is the case that the marginal on-farm value is between the acquisition and salvage prices. Then, the asset is said to be trapped in its current usage in the farm. Generally speaking, this theoretical framework is a static model coupled with an ad hoc operational definition of a fixed asset by introducing an "acquisition/salvage price differentials" mechanism. But G. L. Johnson's pioneering attempt to endogenize the determination of fixed and variable factors provides a generalization of the neoclassical theory of the firm.

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[1] Arrow acknowledges the significant divergence between the acquisition cost and salvage value as follows: "From a realistic point of view, there will be many situations in which the sale of capital goods cannot be accomplished at the same price as their purchase. There are installation costs, which are added to the purchase price but cannot be recovered on sale; indeed, there may on the contrary be additional costs of detatching and moving machinery. Again sufficiently specialized machinery and plants have little value to others. So resale prices may be *substantially* below replacement costs" (p. 2). But he went to the other extreme by assuming that investment is always irreversible (in the sense that no disinvestment is allowed). The analysis of disinvestment ($I \leq 0$) is considered a trivial duplicate of the analysis of investment ($I \geq 0$), and thus both the former and AFT have been disregarded in the literature.

Although AFT provides hypothesized linkages between asset fixity and nonreversibility of supply response, its ad hoc operational definition has been subject to criticisms; moreover, it has been difficult empirically to implement the asset evaluation method. The debate over the definition and existence of asset fixity involves both theoretical and empirical points of view. In order to test the asset fixity hypothesis, Chambers and Vasavada (1983) employ a putty-clay technology and apply the Fuss test to U.S. agricultural aggregate data. Their results show no fixity involving capital, labor, or materials in U.S. agriculture. Edwards (1985) argues that the putty-clay technology proposed by Chambers and Vasavada bears no resemblance to the asset fixity proposed by G.L. Johnson 1956, 1960, 1982. Also some degree of disaggregation is required in order to characterize the role of the fixed asset.

M. A. Johnson and Pasour criticize AFT because the opportunity cost of an asset once acquired cannot always be expected to equal its historical acquisition cost which is irrelevant for current decisions. They claim that the efficient asset market should take into account the concept of choice-influencing costs in asset evaluation and the rational producer behavior. Thus, they conclude that AFT is "inconsistent with rational behavior" (p. 3). G. L. Johnson (1982) argues that AFT considers current acquisition costs to be relevant for determining which assets are fixed. Moreover, AFT not only recognizes the importance of opportunity costs in the resource allocation among alternative uses but also clarifies the role of opportunity costs in the neoclassical theory of the firm. Bradford also criticizes M.A. Johnson and Pasour (1981) for ignoring intertemporal opportunity costs of durable resources which are indispensable for a firm's optimal investment/disinvestment decision making.

The recent development in dynamic adjustment cost models shows another direction in modeling asset fixity by stressing sluggishness in input adjustment as a form of asset fixity (Vasavada and Chambers, Taylor and Monson). The empirical applicability of the dynamic adjustment cost model has been useful in identifying the quasi-fixed asset and the magnitude of their quasi-fixity, but their relationship to nonreversibility in output supply and input demand is unclear. Chang and Stefanou further expand the model by incorporating asymmetry in input adjustment. The relationship between asset quasi-fixity and production nonreversibility is established upon the asymmetric adjustment rates of quasi-fixed inputs.

A common weakness in both the symmetric and asymmetric adjustment cost models is the misleading use of quasi-fixity as a form of asset fixity. G. L. Johnson's asset fixity theory emphasizes why an asset is trapped in its current use and results in a "zero" investment. However, the quasi-fixity in the dynamic adjustment cost models suggests a "nonzero" investment (or disinvestment) of an asset through the sluggish adjustment along the firm's optimal expanding (or contracting) production plan. In this sense, asset fixity becomes a missing piece in the literature of costs of adjustment.

The main purpose of this article is to extend the adjustment cost theory of dynamic firm behavior and rationalize the asset fixity theory.[2] It suggests that by relaxing the smoothness assumption of the adjustment cost function at the origin, the theory of costs of adjustment can provide a rigorous endogenization of asset fixity. It is found that because of its static optimization nature, G. L. Johnson and Edwards' model represents the case when the cost of adjustment functions are linear. The linkage between G. L. Johnson's asset fixity theory and the dynamic adjustment cost model is thus established.

The next section lays out the basic model as that analyzed in Rothschild.[3] To sharpen the nature of asset fixity, the linear adjustment cost function then is first considered, and optimal firm behavior under both symmetric and asymmetric specifications is analyzed. Asset fixity then is imbedded in a more general costs of adjustment model. The final section summarizes the results with comments on extensions and future research.

[2] The rationalization of the asset fixity theory is parallel to that of the flexible accelerator using the dynamic adjustment cost model. The flexible accelerator hypothesis provides a theoretical linkage between the long-run desired capital stock which is determined by static theory and the actual observed capital stock through an ad hoc stock adjustment mechanism. Although the simplicity of the flexible accelerator hypothesis has important advantage in empirical work, its ad hoc nature has been subject to criticisms (e.g., Lucas, Gould, Treadway). The dynamic adjustment cost literature (e.g., Eisner and Strotz, Lucas) began with attempts to rationalize this ad hoc flexible accelerator.

[3] The conclusion of this article does not change when other dynamic adjustment cost models are used. For example, Treadway's model (1969) with the imposition of assumptions (2.1)–(2.5) will give similar results but requires the application of maximum principle. Furthermore, generalization to multiple quasi-fixed inputs should provide more insights into AFT but with more complexity. As far as the rationalization of AFT is concerned, Rothschild's model is preferred because of its relative generality and simplicity.

A Dynamic Model of the Competitive Firm

Consider a competitive firm that sells Q units per period of a single product at a unit price P. The product is assumed instantaneously produced using two factors of production, a variable factor called labor services which is hired in a quantity L at a wage rate $W(t)$ and the services of a quasi-fixed factor called capital, a stock K of which incurs a service charge of $G(t)K$ in period t. All markets faced by the firm are assumed competitive and all prices remain constant over the future; that is, the firm holds with certainty static expectations on all prices. The production function $F(K, L)$ is assumed nondecreasing, concave, twice continuously differentiable, has strictly convex isoquants, and satisfies $F(K, 0) = 0$.

Let

$$(1) \quad \nu(K, P, W, G) \equiv \max_{L \geq 0} [(PQ - WL) - GK],$$

where $Q = F(K, L)$ and $\nu(K, P, W, G)$ [or simply $\nu(K)$] represents the maximum profits that the firm gains from having capital stock K in period t. Let the revenue PQ be always bounded above. Since $\nu(K)$ is a strictly concave function of K, it attains an unique maximum on $[0, \infty)$.

The critical remaining assumption is the functional form of the costs of adjustment $C(I)$, where I is the gross investment. It is assumed that

$$(2.1) \qquad C(0) = 0;$$

$$(2.2) \qquad C(I) > 0 \text{ for } I \neq 0;$$

$$(2.3) \quad C'(I) \text{ exists for all } I \text{ except } I = 0, \text{ i.e., } C'(I) \text{ is discontinuous at } I = 0;$$

$$(2.4) \quad \text{both } \lim_{I \to 0^+} C'(I) \text{ and } \lim_{I \to 0^-} C'(I) \text{ exist, but } \lim_{I \to 0^+} C'(I) \text{ is not equal to } \lim_{I \to 0^-} C'(I);$$

$$(2.5) \qquad \text{sign } C'(I) = \text{sign } I \text{ for } I \neq 0.$$

Assumptions (2.1) and (2.2) imply that $C(I)$ has a minimum at 0; hence if $C'(0)$ exists, it must equal 0. Assumptions (2.3) and (2.4) relax the smoothness restriction on $C(I)$. The discontinuity of $C'(I)$ at the origin implies that in the neighborhood of $I = 0$ the adjustment cost of investment, e.g., installation costs, cannot be recovered on sale (when disinvestment occurs); conversely, the adjustment cost of disinvestment, e.g., costs of detatching and moving machinery, cannot be recovered when investment occurs.[4,5] Loosely speaking, this recognizes the existence of the gap between the acquisition cost and salvage value. Furthermore, we do not restrict our attention to convex adjustment cost functions. Other forms of adjustment cost function (e.g., linear, concave, and piecewise convex or concave) are also allowed.

Suppose that the firm can borrow or lend in a competitive capital market at a positive, constant interest rate r. At any point in time $t = 1$ (called a base period), this price-taking firm chooses the sequence of investment $I = [I_1, I_2, \ldots]$ to maximize the following infinite horizon problem:

$$(3) \quad \mathcal{T}(K_0, I, P, W, G) \equiv \sum_{t=1}^{\infty} [\nu(K_t, P, W, G) - C(I_t)](1 + r)^{-t},$$

subject to

$$(4) \quad K_t = K_{t-1} + I_t \qquad t = 1, 2, \ldots, K(0) = K_0 > 0.$$

Because the introduction of depreciation into this model will not alter the results, depreciation is ignored. As the base period changes and new market prices are observed, the firm revises its expectations and its previous plans; hence in general only the $t = 1$ part of the plan corresponding to (3) and (4) is carried out.

Only necessary conditions are emphasized in this article. Sufficient conditions to ensure the existence of an optimal solution can be found in Rothschild.

The Linear Costs of Adjustment and Optimal Firm Behavior

In order to delineate the relationship between the asset fixity theory and the theory of costs of adjustment, the linear adjustment cost function is

[4] A similar phenomenon was conjectured by G. L. Johnson when he wrote, "Every farm boy knows that selling such assets or the services they produce is quite a different matter from buying them. *Discontinuities* are far more characteristic than perfect elasticities" (G. L. Johnson 1960, p. 27).

[5] The concept of costs of adjustment is so primitive such that its economic interpretation is quite flexible. For example, transportation, risk, legal fees, brokerage, spoilage, contracting, insurance, and other like costs are also involved. This kind of flexibility is indeed one of the sources of its power.

first considered.[6] Also, this section will discuss both symmetric and asymmetric adjustment cost functions, analyze their respective implications on optimal firm behavior, and stress the importance of the behavior of $C(I)$ at the origin in determining the nature of the firm's investment program.

Suppose adjustment cost functions are linear, e.g.,

$$(5)\qquad C(I) = \begin{cases} aI & \text{if } I \geq 0, \\ -bI & \text{if } I \leq 0; \end{cases}$$

where $a > 0$, $b > 0$. See figure 1. The kink at the origin indicates that $C'(I)$ is not continuous at $I = 0$. But both left-hand and right-hand limits of $C'(0)$ exist, and $\lim_{I\to 0^-} C'(I) = -b$, $\lim_{I\to 0^+} C'(I) = a$.

Because of the linearity of the adjustment cost function, the firm saves nothing by slow adjustment; hence, all the adjustment (either investment or disinvestment) will be bunched in the first period only (see theorem III in Rothschild, p. 617). Thus, $I_2 = I_3 = \ldots = 0$ and $K_1 = K_2 = K_3 = \ldots$. The optimal investment program is found by solving the following control problem:

$$(6)\qquad \begin{cases} \max \mathcal{T}(K_0, I) \text{ subject to } I_t \geq 0, \\ \max \mathcal{T}(K_0, I) \text{ subject to } I_t \leq 0; \end{cases}$$

where

$$\begin{aligned}(7)\quad \mathcal{T}(K_0, I) &= \sum_{t=1}^{\infty} [v(K_{t-1} + I_t)(1 + r)^{-t} \\ &\quad - C(I_t)(1 + r)^{-t}] \\ &= v(K_0 + I_1) \sum_{t=1}^{\infty} (1 + r)^{-t} \\ &\quad - C(I_1)(1 + r)^{-1} \\ &= (1 + r)^{-1} [v(K_0 + I_1) \\ &\quad \cdot \frac{(1 + r)}{r} - C(I_1)].\end{aligned}$$

By the Kuhn-Tucker Theorem, if I_1^* (or simply I^*) is the optimal investment, it follows that

$$(8)\qquad \begin{Bmatrix} \mathcal{T}'(K_0, I^*) \leq 0 \text{ and } I^*\mathcal{T}'(K_0, I^*) = 0, \\ \mathcal{T}'(K_0, I^*) \geq 0 \text{ and } I^*\mathcal{T}'(K_0, I^*) = 0, \end{Bmatrix} \text{ when } \begin{cases} I^* \geq 0 \\ I^* \leq 0, \end{cases}$$

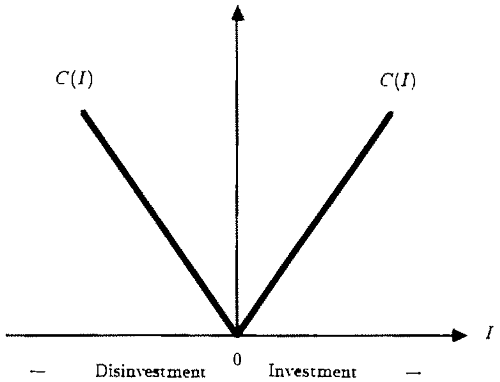

Figure 1. Linear symmetric adjustment cost function

where $\mathcal{T}'(K_0, I^*)$ denotes the derivative of $\mathcal{T}$ with respect to I and is evaluated at I^*. This derivative may not exist at $I^* = 0$ but both $\lim_{I^*\to 0^-} \mathcal{T}'(K_0, I^*)$ and $\lim_{I^*\to 0^+} \mathcal{T}'(K_0, I^*)$ exist.

Equation (8) implies a two-stage decision process: (stage I) whether to adjust or not (i.e., $I^* \neq 0$ or $I^* = 0$), and (stage II) by how much. By combining equations (7) and (8) with the discontinuity of the $C'(I)$ at the origin, the stage I decision rule can be derived as follows: Whenever

$$(9.1)\qquad \left(\frac{r}{1 + r}\right) \lim_{I\to 0^-} C'(I) < v'(K_0 + I^*) < \left(\frac{r}{1 + r}\right) \lim_{I\to 0^+} C'(I);$$

or, in this example,

$$(9.2)\qquad -b\left(\frac{r}{1 + r}\right) < v'(K_0 + I^*) < a\left(\frac{r}{1 + r}\right),$$

no adjustment is needed, i.e., $I^* = 0$, and the initial capital stock K_0 is fixed. The difference between $(r/1 + r) \lim_{I\to 0^-} C'(I)$ and $(r/1 + r) \lim_{I\to 0^+} C'(I)$ can be viewed as the "asset fixity trap" which is conjectured by G. L. Johnson (1982) when they assert that an asset is fixed if on-farm opportunity costs are bounded by off-

[6] Similar results in this section can be obtained when the cost of adjustment function is concave. In this case the best policy for the firm would be to take advantage of decreasing marginal cost of adjustment (either investment or disinvestment) and concentrate its response to changes in market conditions in a single period.

farm opportunities for acquisition and salvage or "if it ain't worth varying." (Edwards 1959, p. 749)

If $v'(K_0 + I^*)$ is not locked inside the asset fixity trap, i.e., the initial capital stock K_0 is not viewed as a fixed asset, then $I^* \neq 0$ and the stage II decision determines the extent of investment or disinvestment. From equation (8), the optimal adjustment I^* must be a solution to the equation $\mathcal{F}'(K_0, I) = 0$. As a result, the decision rule can be characterized as follows:

$$(10.1)\quad v'(K_0 + I^*) = \left(\frac{r}{1+r}\right) C'(I^*);$$

or, in our case,

$$(10.2)\quad v'(K_0 + I^*) = \left\{\begin{matrix} a\left(\frac{r}{1+r}\right) \\ -b\left(\frac{r}{1+r}\right) \end{matrix}\right\} \text{ if } \left\{\begin{matrix} I^* > 0, \\ I^* < 0. \end{matrix}\right.$$

When investment (or disinvestment) is needed, marginal cost of adjustment must be equated to marginal present value. Thus conditions (10.1) and (10.2) resemble the familiar marginal principles of neoclassical production theory. Traditionally, the role of opportunity costs in neoclassical theory has been disciplined to generate the stage II decision rule. Therefore, it is clear that, contrary to M.A. Johnson and Pasour's (1981) assertion, asset fixity theory does not ignore the importance of opportunity costs but rather clarifies their role in the neoclassical theory of firm.

Symmetric Costs of Adjustment: (a = b)

The optimal firm behavior is illustrated by figure 2. For simplicity, we assume that $v'(K_0 + I)$ is linear in I. Also notice that the LHS of equation (10.1) is a decreasing function of I and the whole schedule $v'(K_0 + I)$ will shift downwards as the initial stock K_0 increases. Let K_0^i,

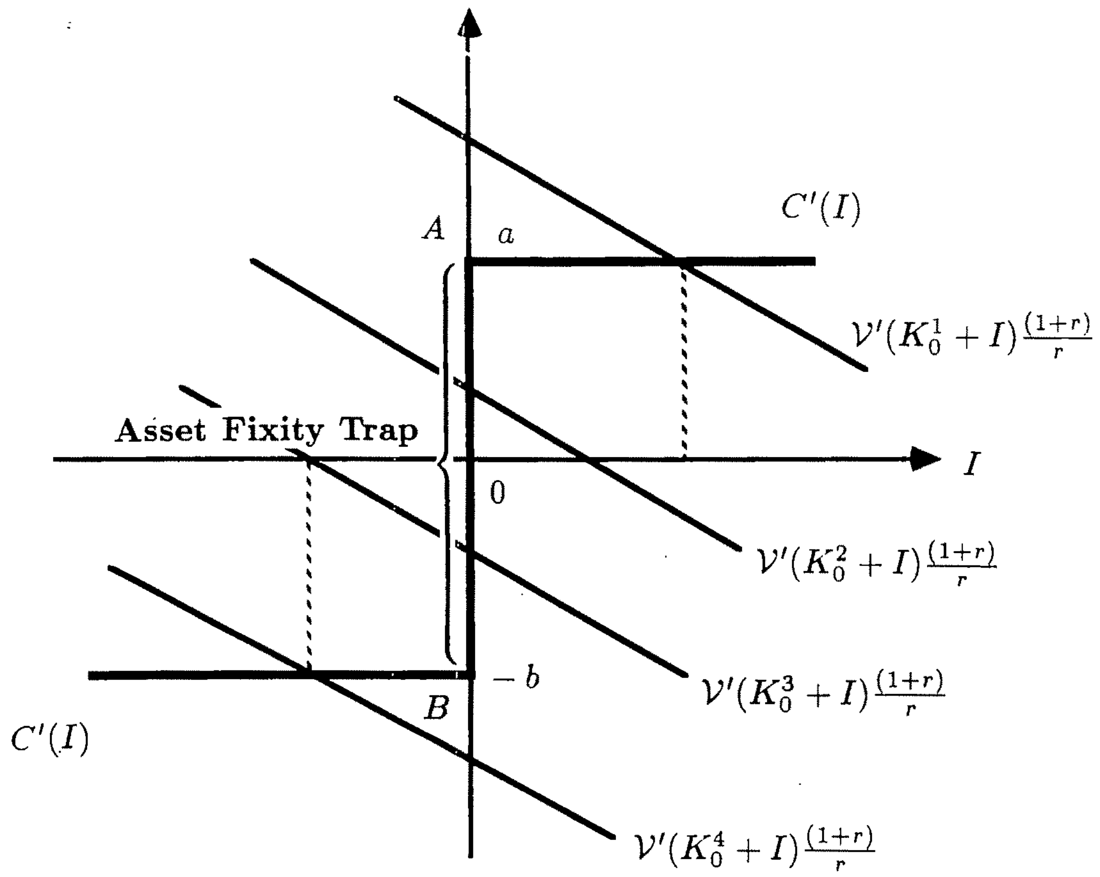

Figure 2. Optimal behavior with linear symmetric adjustment cost

($i = 1, 2, \ldots$) denote different initial stocks where $K_0^i < K_0^j$ if $i < j$. AC, SV, and $v'(K_0 + I)$ schedules can be viewed as the generalized concepts of acquisition cost, salvage value, and marginal value product of I, respectively. See the similarities between figure 2 and Edwards' figure 1 (p. 751) except that here the picture has been translated to the origin due to the "flow" concepts of investment and disinvestment.

Figure 3 is the phase diagram which describes the scenarios of dynamic adjustment process toward equilibrium (Treadway 1970). With the existence of the asset fixity trap, the equilibrium is no longer unique. From equation (9.2), a conceivable range of capital stock levels is allowed for the case of no adjustment ($I^* = 0$), which is shown by the section between points A and B. If the initial market conditions are such that the current capital stock falls inside the asset fixity trap AB, the asset is considered in equilibrium and no adjustment is necessary. Once the market conditions (e.g., prices) change or the firm modifies its expectations, the current stock level may fall outside the trap and adjustment may occur (as the case where K_0 is located at K_0^1 and K_0^4). Thus, an asset can be viewed as putty in the first period, clay in the second period, then putty again in the third period, and so on. In this sense, a simple putty-clay technology as suggested by Chambers and Vasavada (1983) cannot be compared with the asset fixity hypothesis.

In general, inside the asset fixity trap, small changes in market conditions will not cause any adjustment. If we impose the symmetry assumption on the costs of adjustment functior (i.e., $a = b$) like figure 1, the analysis indicate: that producers have the same responses to both price increases and price decreases when inside and outside the asset fixity trap. See figure 2. However, this cannot explain the fact that U.S. agricultural production displays a greater capacity to expand than to contract.

Asymmetric Costs of Adjustment: ($a \neq b$)

Without loss of generality, we assume $a < b$ for the case where it costs more to contract than to expand (see fig. 4).[7] Inside the asset fixity trap AB in figure 5, AO is much shorter than OB. It appears that the tendency to expand is much more sensitive to market conditions than that to contract. For example, with the initial K_0^2, the firm may plan to invest in response to a favorable market situation. On the other hand, with the same K_0^2, a more dramatic change in market conditions is required for the firm to disinvest. This asymmetric case provides a better explanation of Johnson's hypothetical link between asset fixity and nonreversible supply response than the symmetric one.

The Convex Costs of Adjustment and Optimal Firm Behavior

The concept of asset fixity can be easily imbedded into more general costs of adjustment models

[7] It is also possible that $a > b$. This firm, for example, may have accumulated knowledge from previous experience such that he (or she) has greater capabilities to contract than to expand in response to unfavorable market situations.

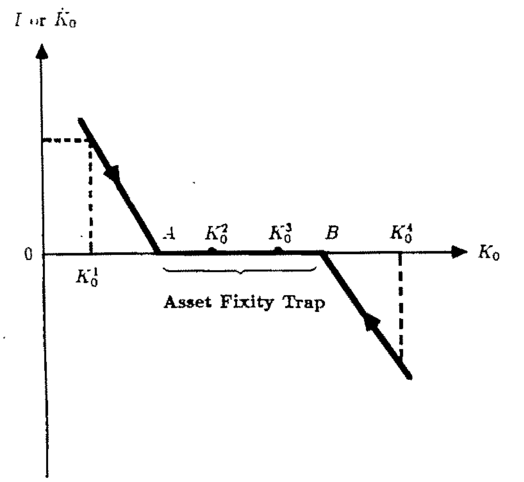

Figure 3. Phase diagram of capital stock adjustment

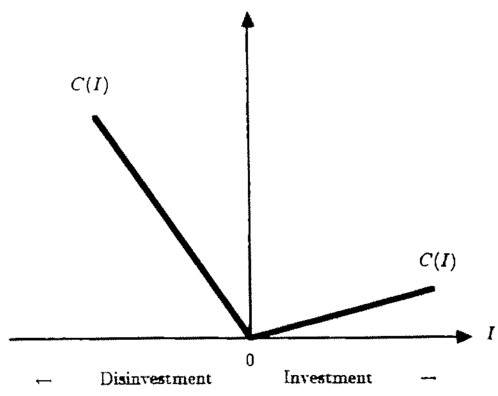

Figure 4. Linear asymmetric adjustment cost function

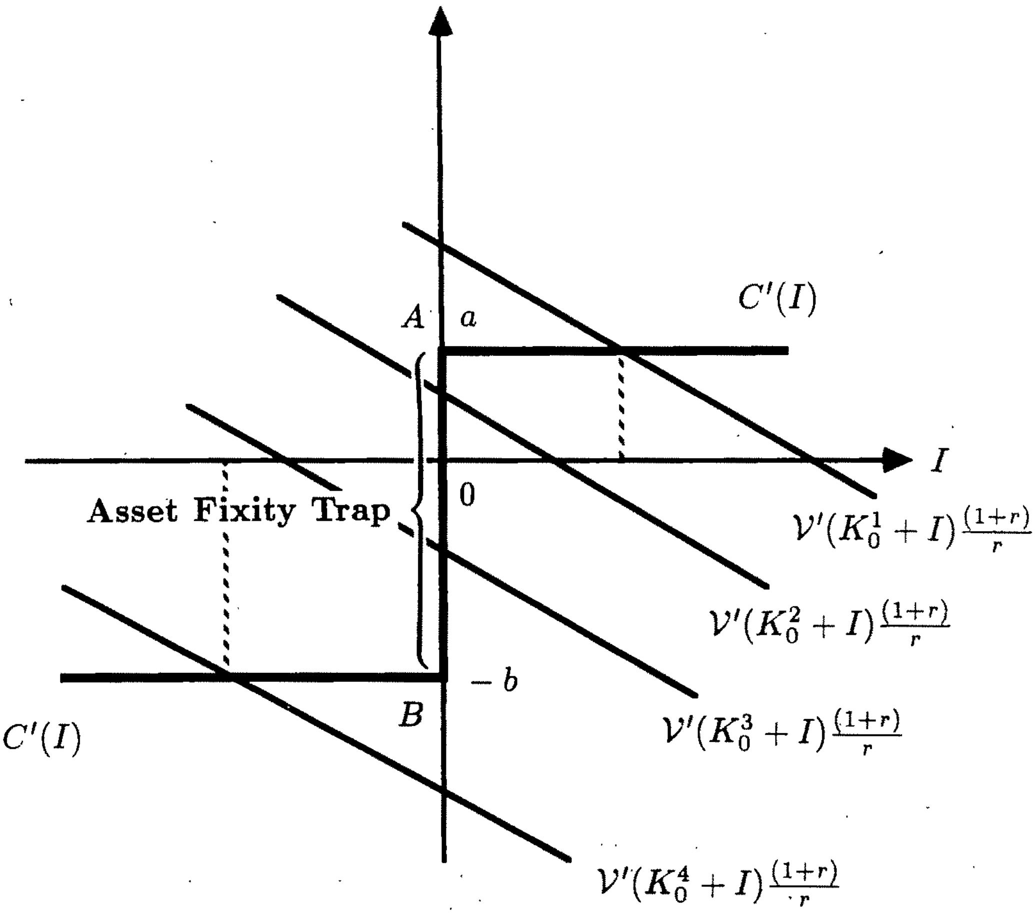

Figure 5. Optimal behavior with linear asymmetric adjustment cost

Because the quadratic ones are widely adopted in the literature, this section deals solely with a generalized version of quadratic adjustment cost function of the form

(11)
$$C(I) = \begin{cases} a\left(I + \sqrt{\dfrac{b}{a}}\right)^2 - b, & \text{if } I \geq 0, \\ c\left(I - \sqrt{\dfrac{d}{c}}\right)^2 - d, & \text{if } I \leq 0; \end{cases}$$

where $a > 0$, $b \geq 0$, $c > 0$, and $d \geq 0$. Clearly, this function satisfies all the assumptions in (2).

Nonsmoothness of C(I) at the Origin:

Let $b > 0$ or $d > 0$ and the function is shown in figure 6. Obviously $C'(I)$ exists for all I except when $I = 0$. Here $\lim_{I\to 0^+} C'(I) = 2\sqrt{ab}$ and $\lim_{I\to 0^-} C'(I) = -2\sqrt{cd}$. It turns out that $\lim_{I\to 0^-} C'(I) < \lim_{I\to 0^+} C'(I)$. Since $C(I)$ is strictly convex, theorem II of Rothschild (p. 616) applies: If the firm responds at all to changes in market conditions, it will distribute its response over all periods; that is, if there is investment in the first period, $I_1 \neq 0$, then $I_2 \neq 0$, $I_3 \neq 0$, ... Thus, of particular importance is the first period in which an intertemporal decision is made and all future returns of I_1 must be considered.

Analogous to the dynamic optimization problem in the preceding section, it follows that the firm faces the following situation:

(12)
$$\begin{cases} \text{Max } \mathcal{T}(K_0, I) \text{ subject to } I_t \geq 0, \\ \text{Max } \mathcal{T}(K_0, I) \text{ subject to } I_t \leq 0; \end{cases}$$

where

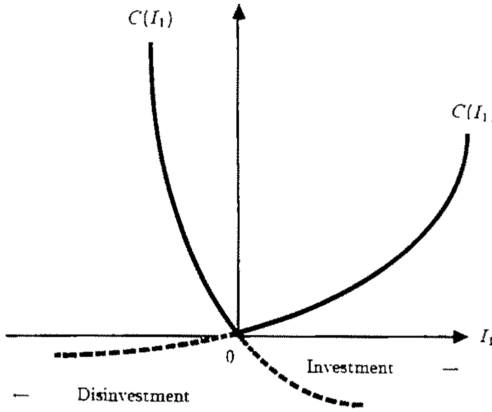

Figure 6. Quadratic asymmetric adjustment cost function

$$(13) \quad \mathcal{T}(K_0, I) = \sum_{t=1}^{\infty} [\nu(K_0 + I_1 + \ldots + I_t) \cdot (1 + r)^{-t} - C(I_t)(1 + r)^{-t}].$$

Let $I^* = [I_1^*, I_2^*, \ldots]$ be the optimal future plan decided in the first period. From the Kuhn-Tucker Theorem the stage I decision rule at period 1 is developed as follows: Whenever

$$(14.1) \quad \lim_{I_1 \to 0^-} C'(I_1) < \sum_{t=1}^{\infty} \nu'(K_0 + I_1^* + \ldots + I_t^*) \cdot (1 + r)^{-t+1} < \lim_{I_1 \to 0^+} C'(I_1);$$

or, combined with the specification of (11),

$$(14.2) \quad -2\sqrt{cd} < \sum_{t=1}^{\infty} \nu'(K_0 + I_1^* + \ldots + I_t^*) \cdot (1 + r)^{-t+1} < 2\sqrt{ab},$$

no adjustment (investment or disinvestment) will occur, that is, $I_1^* = 0$ and $I^* = 0$. Therefore, K_0 is trapped in the production and is viewed as fixed. The difference between $\lim_{I \to 0^-} C'(I)$ and $\lim_{I \to 0^+} C'(I)$ leads to the phenomenon of the asset fixity trap as in the linear costs of adjustment case.

If $I_1^* \neq 0$, that is, if $\Sigma_{t=1}^{\infty} \nu'(K_0 + I_1^* + \ldots + I_t^*)(1 + r)^{-t+1}$ is outside the asset fixity trap, then I_1^* should satisfy the following marginal principle rule:

$$(15.1) \quad \sum_{t=1}^{\infty} \nu'(K_0 + I_1^* + \ldots + I_t^*) \cdot (1 + r)^{-t+1} = C'(I_1^*);$$

or, in our case,

$$(15.2) \quad \sum_{t=1}^{\infty} \nu'(K_0 + I_1^* + \ldots + I_t^*)(1 + r)^{-t+1} = \begin{Bmatrix} 2(aI_1^* - \sqrt{ab}) \\ 2(cI_1^* - \sqrt{cd}) \end{Bmatrix} \text{ if } \begin{cases} I^* > 0, \\ I^* < 0. \end{cases}$$

An interpretation similar to the linear case can be drawn from figure 7. Of particular interest is the appearance of asymmetry in both the asset fixity trap, AB, and quasi-fixity along $C'(I_1)$. Here it may suffice to quote G.L. Johnson and Quance: "Irreversibility is taken to mean responses to price decreases which are not the exact opposites of corresponding increases. Generally, the theoretical output responses to product price increases should be expected to exceed the contractions associated with product price declines. Similarly, expansions in use of inputs resulting from product price increases and input price decreases should be expected to be greater than the contractions resulting from comparable product price declines and input price increases" (pp. 190–91). As a result, when asset fixity is coupled with a second-best allocative efficiency mechanism to minimize losses after an initial error (Johnson and Quance, chap. 4; G. L. Johnson 1982, p. 774), this type of asymmetric adjustment cost model can provide a better factual and analytical basis for the overproduction trap in U.S. agriculture.

Both nonsmoothness at the origin and asymmetry of $C(I)$ have important implications in explaining the traditional farm adjustment problem. Unfortunately, the former has been ignored by almost all the literature on adjustment cost models and their corresponding empirical applications. Only Rothschild comes close to this point by emphasizing the importance of the behavior of the adjustment cost function near the origin in determining the nature of the firm's investment decision. However, it is the behavior at the origin which brings in the recognition of a fixed asset and its degree of fixity.

Smoothness of C(I) at the Origin:

When $b = d = 0$ and $a = c$, $C(I)$ in equation (11) reduces to the popular one in the literature (e.g., Gould, pp. 48–49; Sargent, p. 133). Here, $C(I)$ is continuously differentiable everywhere; in particular, $C'(0)$ exists and equals to 0. See figure 8. Thus,

$$\lim_{I \to 0^-} C'(I) = \lim_{I \to 0^+} C'(I) = 0,$$

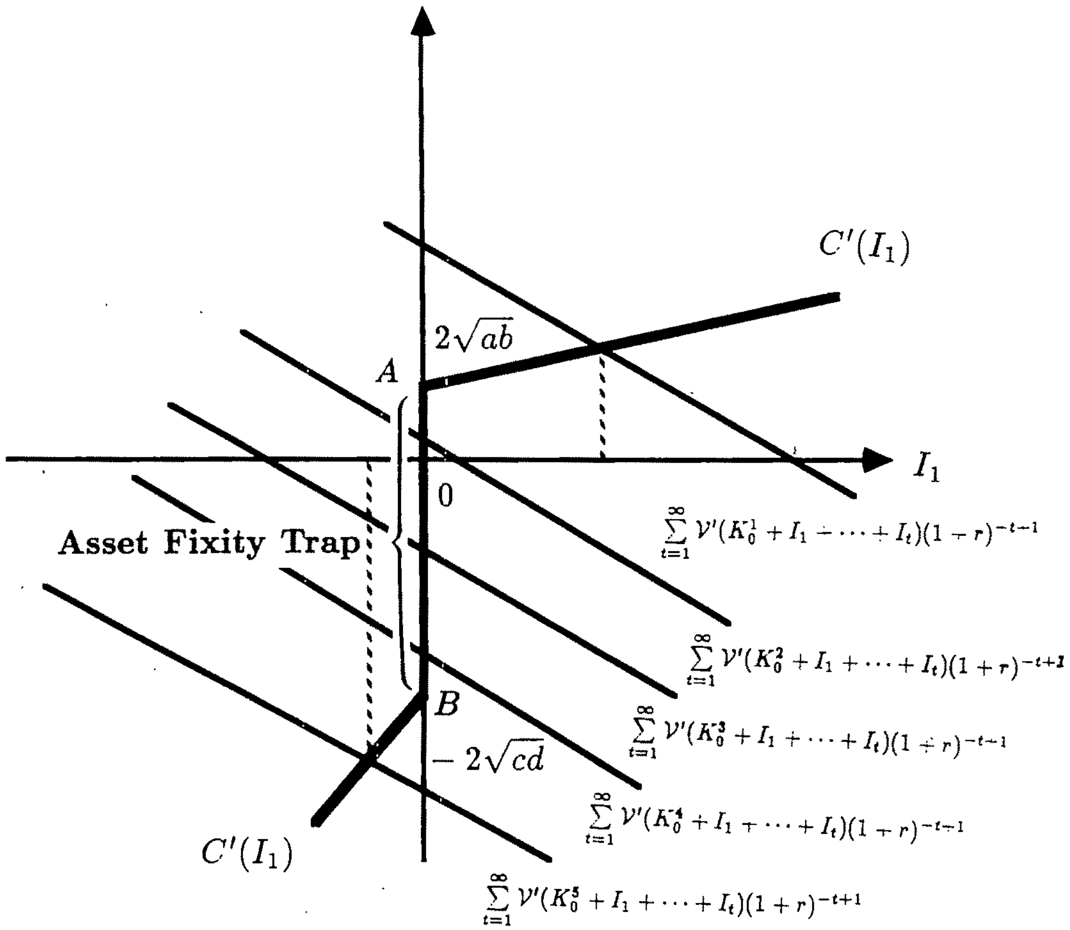

Figure 7. Optimal behavior with quadratic asymmetric adjustment cost

and the asset fixity trap disappears altogether in figure 9. The firm then will respond to almost any change in market conditions; that is, nothing is fixed. However, some degree of sluggishness in factor adjustment can still be captured in terms of asset quasi-fixity. Similar arguments can be drawn from more general cost of adjustment functions. Hence, unless the smoothness assumption of $C(I)$ at the origin is relaxed, such specifications, either symmetric or asymmetric, can at most be justified in explaining asset quasi-fixity rather than the real asset fixity proposed by Johnson.

Concluding Comments

Existing rationalizations of asset fixity theory have been incomplete because they have relied on static models coupled with an ad hoc acquisition/salvage price differentials hypothesis. This article has clarified the theory of asset fixity through the introduction of dynamic adjustment cost.

The principal conclusions of the analysis are the following: First, by inspecting the asset fixity theory under the dynamic adjustment cost framework, one can obtain a theory which is much richer in its implications for the asset fixity and asset quasi-fixity. Because of the static nature of their model, Johnson and Edwards' results are obtained when the linearity assumption of the costs of adjustment function is imposed. Second, from the above discussion, the costs of adjustment theory provides not only a theoretical justification for the use of distributed lags in econometric studies of investment but also a rigorous endogenization of asset fixity. In this sense, the costs of adjustment theory is a further generalization of the neoclassical analysis and hence is indispensable for a complete "theory of in-

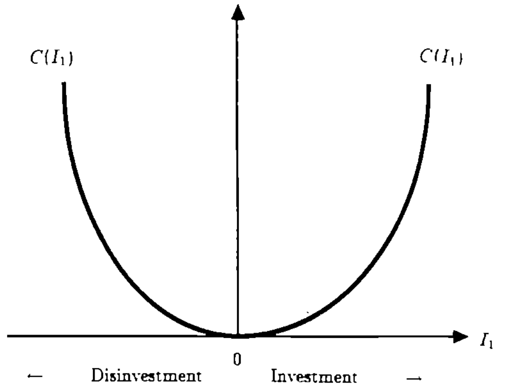

Figure 8. Quadratic symmetric adjustment cost function

vestment/disinvestment" in the sense of G. L. Johnson (1982, p. 775).

Third, it is not the behavior of $C(I)$ near the origin, either convexity or concavity, which guarantees the existence of asset fixity but the discontinuity of $C'(I)$ at the origin. Without this crucial specification the popular quadratic cost function can only capture some degree of sluggishness of factor adjustment in terms of asset quasi-fixity, but not asset fixity. This is one of the important reasons why most theoretical work on the theory of adjustment cost has had little or no impact on empirical investigations of asset fixity. Therefore, tests of asset fixity using conventional econometric techniques are doomed to failure. No wonder Chambers and Vasavada (1985, p. 139) assert that "the theory (of asset

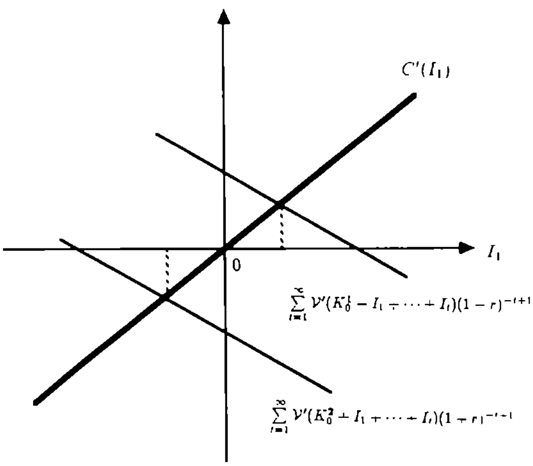

Figure 9. Optimal behavior with quadratic symmetric adjustment cost

fixity) still remains untested and, as such, appears to border on what Joan Robinson has defined as a metaphysical proposition."

The work reported here also implies that both smoothness of $C(I)$ at the origin and symmetry of $C(I)$ should be subject to empirical tests. Although the underlying analysis is carried out at the micro level, it has important implications for aggregate studies on supply response and investment (or disinvestment) behavior. The literature on estimating nonreversible supply functions (Tweeten and Quance; Wolffram; Houck; Traill, Colman, and Young) utilize a price-segmenting method to specify the aggregate supply response model. An appealing econometric extension of the research on asset fixity is to incorporate the segmenting idea into the cost of adjustment function. The further expansion to allow for regime changes and asymmetric response will enrich the contents of the dynamic model in terms of empirical applications. Also deservedly dominating our attention are equations (10.1) and (10.2) which are piecewise continuous differential equations with the right-hand side discontinuities. Such kind of equations are the major concern of the variable structural system (VSS) approach.[8] To avoid the aggregation difficulties with AFT (Edwards 1985, p. 136), the VSS approach endogenously partitions the intertemporal decision-making problem into two subsystems: one is in the expansion (i.e., investment) regime; the other is in the contraction (i.e., disinvestment) regime. The analysis of the firm's optimization behavior in these two regimes ($I^* \neq 0$) may provide insight for unveiling the mysteries of asset fixity trap ($I^* = 0$) (e.g., Chang and Stefanou).

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[8] The theory of VSS has been developed over the last thirty years almost exclusively in the USSR. The survey paper of Utkin has several references. Chen, Hsu, and Lozada (chap. 7) provides an introduction to the theory of VSS and some of its applications in economics.

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Farmers' Marginal Propensity to Consume: An Application to Illinois Grain Farms

Michael R. Langemeier and George F. Patrick

The marginal propensity to consume (MPC) for a sample of eighteen Illinois farms over the 1979–86 period is determined. Four consumption models were estimated using disposable household income plus depreciation as the measure of income. Estimated short-run MPCs ranged from 0.007 to 0.020, while long-run MPCs varied between 0.143 to 0.381. These results indicate farm family consumption responded little to changes in income and that the life cycle hypothesis model explains consumption significantly better than the other models. Robustness of the results is demonstrated using a larger sample of farms for 1986–87.

Key words: farm consumption, income volatility, marginal propensity to consume.

Consumption behavior of a farm family affects firm growth, debt repayment, and the firm's responses to policy changes. Pederson and Brake gave two important reasons for including family living expenditures in financial analysis: (*a*) family consumption reduces the firm's ability to acquire assets; (*b*) family living expenditures are a measure of the farm family's standard of living. Policy analysts are also interested because farmers' consumption behavior affects the reaction of input use, investment, and debt repayment to changes in agricultural and economic policy.

Empirical studies on the relationship between farm consumption and income are not prevalent because of the sparsity of high quality data on family living expenditures. Previous studies that have estimated consumption functions based on individual farm observations include MacMillan and Loyns; Girao, Tomek, and Mount; Leon and Rainelli; Mullen, Powell, and Reece; and Beck and Dent. Of these, only the Girao, Tomek, and Mount study analyzed the consumption behavior of U.S. farmers. The data used in their study are now almost twenty years old. Since then the farm economy has undergone substantial change.

The purpose of this study is to determine the marginal propensity to consume for a sample of Illinois farms for the 1979–86 period. Models based on the partial adjustment, relative income, permanent income, and life cycle hypotheses are used to estimate the marginal propensity to consume. A larger cross section of Illinois farms for 1986–87 is used to evaluate the robustness of the results. Implications of the estimated marginal propensities to consume are then discussed.

Consumption Hypotheses and Models

If farm consumption is less volatile than income, there may be some inertia or habit persistence in farm consumption and the marginal propensity to consume will be relatively low. Habit persistence indicates previous consumption would have a significant influence on current consumption. Consumption lagged one period was used to model habit persistence by Hall and by Sargent.

Several theories have been postulated to explain habit persistence in consumption. Though the models are similar, the way in which habit persistence is modeled differs slightly. In addition to lagged consumption, income and wealth

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are typically hypothesized to have a significant influence on consumption. Recent studies have also included socioeconomic characteristics of the household as variables (Mullen, Powell, and Reece).

Variables used in the discussion below have the following definitions: C is real consumption, IBD is real disposable household income plus depreciation, IBD_o is previous peak level of real disposable household income plus depreciation, PI is real permanent income, NW is real net worth, e is an error term, and t, $t-1$ as subscripts refer to years.

One approach used in modeling habit persistence is the partial adjustment hypothesis. Consumers are assumed to adjust consumption only partially when income fluctuates because of habit or lack of information. The actual change in C from $t-1$ to t is some function of the desired change between periods. Johnston shows that the partial adjustment model can be estimated as

$$(1) \qquad C_t = a_0 + a_1 IBD_t + a_2 C_{t-1} + e_t,$$

where a_0, a_1, and a_2 are regression coefficients. Socioeconomic variables, such as size of the household (HS), age of the head of the household (A), and age of the oldest child (CH), could be added as explanatory variables.

A second model to explain habit persistence is the relative income hypothesis. This hypothesis was developed by Duesenberry to explain variation in the C/I ratio. Duesenberry hypothesized the rich spend proportionally more because of emulation. In addition, individuals become accustomed to a certain standard of living and find it difficult to reduce consumption when income decreases. A model of the form

$$(2) \qquad C_t = b_0 + b_1 IBD_o + b_2(IBD_t - IBD_o) + e_t$$

was used by Mullen, Powell, and Reece to test the relative income hypothesis in Australia. In this equation b_0, b_1, and b_2 are coefficients to be estimated. The coefficient on b_1 and b_2 represent the long-run and short-run marginal propensities to consume, respectively. A lagged consumption variable is not included in equation (2). The previous peak income variable is used instead of lagged consumption to model habit persistence.

A third approach to model habit persistence is the permanent income hypothesis. Friedman distinguished between permanent and transitory components of income and consumption. Permanent consumption was hypothesized to be a function of permanent income. Friedman suggested that permanent income be estimated by a weighted average of current and past income and that measured consumption be used as a proxy for permanent consumption. The model becomes

$$(3) \qquad C_t = c_0 + c_1 PI_t + c_2 C_{t-1} + e_t,$$

where c_0, c_1, and c_2 are regression coefficients. A weighting scheme of $1/2\ IBD_t + 1/3\ IBD_{t-1} + 1/6\ IBD_{t-2}$ is used to model permanent income. Beck and Dent used this weighting scheme to model permanent income. Alternatively, the permanent income hypothesis could be estimated using the adaptive expectations mechanism.

A fourth model to explain habit persistence is the life cycle hypothesis developed by Ando and Modigliani. This hypothesis assumes a consumer's utility is a function of current and future consumption. Utility is maximized subject to current and future earnings and current net worth. Ando and Modigliani suggest using current income as a proxy for future earnings. The life cycle hypothesis can be estimated with the following equation:

$$(4) \qquad C_t = d_0 + d_1 IBD_t + d_2 C_{t-1} + d_3 NW_t + e_t,$$

where d_0, d_1, d_2, and d_3 are regression coefficients.

The four models discussed above are used to estimate the marginal propensity to consume for a sample of Illinois farms. Based on the theoretical models, all of the regression coefficients should be positive. Also, if the income stream of the sample of farms is volatile, the estimated marginal propensities to consume will be relatively small (Friedman). Non-nested hypotheses tests will determine if any of the theoretical models explain consumption significantly better than the others.

Consumption and Income for a Sample of Illinois Farms

Data for this study were obtained from records of families enrolled in Farm Business-Farm Management Associations in Illinois. A subsample, about 325 in 1986, of all cooperating families keep track of the sources and uses of funds. To be considered usable, records must satisfy a number of checks designed to insure completeness and accuracy.

This study used only the eighteen farms that

had usable data for each year from 1979 to 1986. In 1986 these eighteen predominately grain farms had an average of 818 tillable acres, of which 119 acres were owned. The number of tillable acres on these eighteen farms was about 26% greater than the mean of the larger group in 1986, while the acres owned was about 4% less. The average ages of the operator and oldest child were forty-five and thirteen years, respectively, in 1986. The average household size was 3.8 people.

Table 1 presents information on real average annual consumption, disposable household income, disposable household income plus depreciation, and net worth. These series were inflated to 1986 dollars using the implicit price deflator for personal consumption expenditures (U.S. Dept. of Commerce). Average annual total consumption was approximately $32,000 per farm, about 11% above the 1986 average for the 325 farms on which sources and uses of funds are kept.[1]

Disposable household income (net farm income plus net nonfarm income minus taxes) over the period was considerably more variable than consumption, indicating consumption only partially adjusts when income fluctuates.[2] An alternative measure of income, disposable household income plus depreciation, was more closely related to actual funds available for consumption and was less variable than disposable household income.

Consumption exceeded disposable household income on only two farms in 1979, while ten to fifteen farms were in this situation from 1981 to 1984. Consumption is just one of many possible uses of funds. Over the period, consumption exceeded disposable household income by $2,000 per year. In contrast, disposable household income plus depreciation was about $27,500 more than consumption annually. Thus nontaxable receipts, money borrowed, and depreciation were used, in addition to disposable household income, for family living. Average real net worth

[1] Average real total consumption for all farms that kept track of sources and uses of funds in 1979, 1980, 1981, 1982, 1983, 1984, 1985, and 1986 was $33,885, $30,691, $31,299, $28,413, $29,066, $28,220, $27,786, and $28,742, respectively. The total number of farms that kept track of sources and uses of funds varied over the period.

[2] Mean net nonfarm income on these farms was about 22% of net farm income over the period. Nonfarm income was slightly less variable than farm income over the period.

Table 1. Means and Standard Deviation (in 1986 Dollars) of Real Consumption, Income, and Wealth for Eighteen Illinois Farms, 1979–86

Year	Total Consumption	Disposable Household Income	Disposable Household Income Plus Depreciation	Net Worth	Number[a]
1979	32,244[b]	68,894	100,617	330,476	2
	(13,040)[c]	(44,236)	(54,096)	(363,075)	
1980	34,089	33,032	63,202	372,938	8
	(14,887)	(35,695)	(42,296)	(362,001)	
1981	33,513	30,197	61,987	355,669	10
	(10,608)	(43,761)	(46,696)	(389,986)	
1982	29,179	9,792	42,454	326,849	15
	(7,764)	(30,835)	(31,395)	(277,270)	
1983	33,848	19,124	51,324	228,581	13
	(14,321)	(47,971)	(51,486)	(224,468)	
1984	30,887	10,683	39,399	184,585	12
	(8,000)	(31,761)	(33,882)	(191,671)	
1985	30,000	32,649	60,848	105,762	8
	(8,756)	(19,656)	(26,314)	(162,638)	
1986	32,146	33,334	55,545	66,507	9
	(8,695)	(29,328)	(31,473)	(143,810)	
1979–86					
Mean	31,988	29,713	59,422	246,421	10
Std. dev.	(1,826)	(18,667)	(18,858)	(118,183)	

[a] Number of farms in which consumption exceeded disposable household income.
[b] Arithmetic mean for the 18 farms in real terms.
[c] Standard deviations are in parentheses.

per farm peaked in 1980 and declined from 1981 to 1986.[3]

The empirical evidence in table 1 supports the hypothesis of inertia or habit persistence in farm consumption. The coefficient of variation (standard deviation divided by mean) of consumption was 10% of disposable household income and 20% of disposable household income plus depreciation for the sample of farm families. In the analysis below, disposable household income plus depreciation is used as the income measure.

Pooling Time-Series and Cross-Section Data

A pooled data set contains observations over time and over cross sections. A number of different econometric models can be used with pooled data (Kmenta). The econometric model used in this study is the cross-sectionally correlated and timewise autoregressive model described by Kmenta (pp. 622–25). Specifically, the assumptions are that the variance of the error terms for each cross section or family unit differ, the error terms for each cross section are correlated with the error terms of the other cross sections and first-order autocorrelation. The error structure of the model is not known, so an estimated generalized least squares (GLS) approach is needed.

The following test statistic is used to test the null hypothesis of no first-order autocorrelation:

$$Q = T \sum_{k=1}^{n} \hat{r}_k^2, \tag{5}$$

where r is the sample autocorrelation coefficient for each cross section, T is the number of observations in each cross section, n is the number of cross sections, and k represents a cross section. The estimated rho values (first-order autocorrelation statistics) for each cross section are used as the sample autocorrelation coefficients. This test statistic is similar to the (Box-Pierce) Q statistic proposed by Box and Pierce and is distributed as a chi-square distribution with seventeen degrees of freedom in this case. If the null hypothesis of no autocorrelation is rejected, then we conclude that autocorrelation is present.

Three of the four consumption models posited in this study contain a lagged dependent variable. Johnston indicates that using GLS in a model with lagged dependent variables and autocorrelated errors will result in inconsistent estimates. Consistent estimates can be obtained by using an instrumental variable technique. The instruments for the lagged endogenous variable are the first and second lags of the exogenous variables. The instrumental variable technique is not needed for the relative income hypothesis model and is not needed if the error terms are not correlated.

Godfrey and Pesaran explore three tests of the non-nested hypothesis of no significant differences between the alternative econometric models. The orthodox test embeds the non-nested equations in a general specification. The J-test and the Cox test can also be used to test the non-nested hypothesis. This analysis has only one nonoverlapping variable in each consumption model. Thus, the orthodox test will have the same asymptotic power as the J-test and Cox test. Monte Carlo analysis conducted by Godfrey and Pesaran suggests that the J-test has low power in small samples. The Cox test is a paired test so it would be more difficult to apply in this case.

To conduct the orthodox test, the four consumption models are pooled. The null hypothesis for each consumption model is that the coefficients on the variables excluded from that consumption model are not significantly different from zero. If all four null hypotheses are rejected, the pooled model is used. If we fail to reject all four null hypotheses, then we conclude that there is no significant difference between the models. If we reject a subset of null hypotheses, then the models associated with the null hypotheses that we failed to reject explain consumption significantly better than the other models.

Results

The estimated consumption functions are presented in table 2. Theoretical foundations of the different models suggest that the signs of all the independent variables in table 2 should be positive. All of the variables have the expected sign. The hypothesis of no autocorrelation was rejected for each of the four models. Thus, the instrumental variable technique was used to obtain consistent estimates for all models except the relative income hypothesis model.

[3] Nominal net worth peaked in 1981 and declined from 1982 to 1986. Nominal land values in Illinois peaked in 1981 (USDA). Land values declined 48% in nominal terms and 58% in real terms between 1981 and 1986 for both the sample of farms and for Illinois as reported by USDA. Real liabilities increased by about $115,000 from 1979 to 1986.

Table 2. Estimated Consumption Functions for a Sample of Illinois Farms

Independent Variable[a]	Consumption Model: Partial Adjustment	Relative Income	Permanent Income	Life Cycle
Intercept	2,363.990	15,997.800**	3,699.310**	827.554
	(0.770)	(14.279)	(1.538)	(0.251)
C_{t-1}	0.852***		0.830***	0.865***
	(10.588)		(10.992)	(9.743)
IBD_t	0.020**			0.017*
	(2.101)			(1.446)
IBD_o		0.143***		
		(14.862)		
$IBD_t - IBD_o$		0.007*		
		(1.429)		
PI_t			0.026*	
			(1.291)	
A_t	24.912			
	(0.348)			
NW_t				0.008***
				(2.447)
Q[b]	29.398**	25.274*	30.284**	30.249**

Note: The t-ratios are in parentheses. One asterisk denotes significance at the 10% level, two asterisks denote significance at the 5% level, and three asterisks denote significance at the 1% level (one-tailed test).

[a] The independent variables are defined as: C_{t-1} is lagged real consumption, IBD_t is real disposable household income plus depreciation, IBD_o is the previous peak level of real disposable household income plus depreciation, PI_t is real permanent income, A_t is the age of the head of the household, and NW_t is real net worth.

[b] Q is a test of the null hypothesis of no autocorrelation and is distributed as a chi-square distribution with 17 degrees of freedom in this case.

The income variable, IBD_t, was significant for the partial adjustment and life cycle models. For the relative income model, the previous peak income variable IBD_o, and the short-run income effect, $IBD_t - IBD_o$, were significant. Permanent income was significant using the weighting scheme of $1/2\ IBD_t + 1/3\ IBD_{t-1} + 1/6\ IBD_{t-2}$ in the permanent income model.

Lagged consumption, C_{t-1}, was included in the partial adjustment, permanent income, and life cycle models. Not surprisingly, coefficients on lagged consumption were significant in these models. This indicates that the adjustment to fluctuating income, as well as other effects, is not instantaneous.

The age of the operator, A_t, was insignificant in the partial adjustment model, perhaps reflecting the limited range of the age of the heads of households in this sample.[4] Estimation of the life cycle model suggests that the wealth effect, as measured by NW_t, is significant.

Table 3 presents the results of the non-nested hypotheses tests. The null hypothesis for each consumption model is that the coefficients on the variables excluded from that consumption model are not significantly different from zero. The null hypothesis is rejected for the partial adjustment, relative income, and permanent income consumption models. For the life cycle consumption model, we fail to reject the null hypothesis. Thus, the orthodox test results indicate the life cycle consumption model, which includes net worth as a variable, explains consumption behavior significantly better than the other models.

The short-run and long-run marginal propensities to consume (MPC) are reported in table 4. Estimates of the short- and long-run MPCs ranged from 0.007 to 0.020 and 0.143 to 0.381, respectively, using disposable household in-

Table 3. Tests of the Non-Nested Hypotheses

Consumption Model	Orthodox Test Statistic[a]
Partial adjustment	4.592***
Relative income	4.138***
Permanent income	5.901***
Life cycle	2.570

[a] An F-test (Wald test) was used to determine if the excluded variables' coefficients were significantly different from zero. Three asterisks denote significance at the 1% level.

[4] Fifteen of the operators were between 35 to 50 years of age in 1986. The other three operators were over 50 years old.

come plus depreciation as the income measure. These estimates are lower than results from previous studies. However, the range of estimates is smaller than the range of estimates reported in previous studies. For example, Girao, Tomek, and Mount's estimates of the short-run and long-run *MPC*s ranged from −0.047 to 0.243 and from 0.112 to 0.571, respectively. The "best estimates" from Mullen, Powell, and Reece ranged from 0.13 to 0.16 and 0.19 to 0.25. However, Mullen, Powell, and Reece did not estimate the life cycle model. Without the life cycle model, estimates of the short- and long-run *MPC*s ranged from 0.007 to 0.020 and 0.143 to 0.162, respectively, in this study. Mullen, Powell, and Reece do not report a measure of income volatility. The sample of farms used in the Girao, Tomek, and Mount study had incomes that were less volatile than the incomes of the farms used in this study. Friedman suggested that individuals with a volatile income stream will have relatively lower marginal propensities to consume. The results in this study support this contention.

Table 4. Marginal Propensities to Consume for a Sample of Eighteen Illinois Farms for the 1979–86 Period

Model	Short-Run MPC	Long-Run MPC[a]
Partial adjustment	0.020	0.144
Relative income	0.007	0.143
Permanent income	0.013	0.162
Life cycle	0.017	0.381

[a] The long-run marginal propensity to consume except for the relative income model was calculated using the average real growth rate of consumption over the sample period, −0.0108, and the method used by Evans.

Robustness of the Results

The previous analysis used a relatively small sample (18 farms) to investigate farm consumption behavior over an eight-year period. The consumption behavior of a larger sample of farms could have been evaluated over a shorter time period. However, a longer time series permits more precise econometric estimates and allows use of the non-nested hypotheses tests. In this section the robustness of the results is examined by analyzing a cross section of 191 Illinois farms with data for both 1986 and 1987.[5]

Consumption in 1986 for the 191 farms averaged $28,537, while the mean disposable household income and net worth were $51,911 and $125,567, respectively. Average consumption and disposable household income plus depreciation were 11% and 7% lower and net worth was 89% higher for the 191 farms than for the smaller sample of 18 farms. The average ages of the operator and oldest child were forty-five and nine years, respectively, in 1987. The average household size was 3.5 people.

With only two years of data the permanent income model with a weighted three-year lag structure cannot be estimated. Alternatively, a weighting scheme of $1/2\ IBD_t + 1/2\ IBD_{t-1}$ is used for the permanent income model. A more serious problem is associated with estimating the previous peak income variable in the relative income model with only two years of data. This problem will affect both the short-run income measure ($IBD_t - IBD_o$) and the long-run income measure (IBD_o). Because of this, the relative income model was not estimated for the 191 farms.

The short-run and long-run marginal propensities to consume (MPCs) for the 191 farms are reported in table 5. The estimates of the short-run and long-run MPCs ranged from 0.022 to 0.039 and 0.102 to 0.132. A Wald test was conducted to determine if the short- and long-run MPCs for the partial adjustment, permanent income, and life-cycle models were significantly different than the MPCs reported in table 4. Results indicated that short-run MPCs were not significantly different, while the long-run MPCs were significantly different than those reported

Table 5. Marginal Propensities to Consume for a Sample of 191 Illinois Farms for the 1986–87 Period

Model	Short-Run MPC	Long-Run MPC[a]
Partial adjustment	0.039	0.120
Permanent income	0.022	0.132
Life cycle	0.023	0.102

[a] The long-run marginal propensity to consume except for the relative income model was calculated using the average real growth rate over the sample period, 0.0050, and the method used by Evans.

[5] Like the smaller 18 farm sample, these 191 farms are predominantly grain farms located in central Illinois. Because participation in the Illinois Farm Business-Farm Management Association is voluntary, the 191 farms do not constitute a random sample of farms in central Illinois and may not be representative.

in table 4.[6] With only two years of data it is probably not possible to obtain precise estimates of the long-run MPCs.

In summary, the results are not fragile with respect to a larger sample of farms. The short-run MPCs for the larger sample of farms were not significantly different than the short-run MPCs for the smaller sample. The significantly different long-run MPCs is probably due to the short time period used in the estimation with the larger sample.

Conclusions and Implications

This study determined the marginal propensity to consume (MPC) for eighteen Illinois predominately grain farms over the 1979–86 period. The partial adjustment, relative income, permanent income, and life cycle models of consumption were used to specify consumption functions. Results of non-nested hypotheses tests indicated the life cycle hypothesis explained consumption better than the other models. In the life cycle consumption model, lagged consumption, income, and wealth have an influence on consumption behavior. The estimates of the short-run and long-run MPCs ranged from 0.007 to 0.020 and 0.143 to 0.381, respectively.

The low MPC of farm families has important implications for firm behavior. Consumption does not react one-for-one to changes in income. A large increase in income for a particular year will result in a substantially smaller proportional increase in consumption. Thus, money is available for other uses of funds such as expansion of the firm, debt payment, or savings for retirement. Similarly, a decline in income will result in a smaller proportional decrease in consumption. During a low income year, the other uses of funds such as machinery and building purchases, savings, and principal payments would be curtailed. Farmers with low incomes in the 1980s typically reduced expenditures for inputs as well as machinery and buildings, deferred principal payments, did not expand, and tended to maintain family living expenditures. For example, farm tractor purchases and combine purchases dropped 66% and 76%, respectively, from 1979 to 1986 (Federal Reserve Bank of Chicago).

What do the low MPCs imply for researchers and policy analysts trying to model firm behavior? First, models that assume consumption is constant over time are not as ad hoc as they may seem. However, the level of family living expenditures may be much higher than is commonly assumed. Second, consumption becomes a proportionally larger use of funds during low income years. Consumption displaces equipment purchases, debt repayment, and other uses of funds when income is lower than normal. Furthermore, with recovery of the agricultural sector, until incomes exceed the nearly fixed levels of family consumption, increases in farm family income will have little effect on other farm expenditures.

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[6] The Wald test statistics for the short-run *MPC*s are 1.32, 1.03, and 0.10 for the partial adjustment, permanent income, and life cycle models, respectively. The critical *F*-value at the 5% level of significance is 3.90. The Wald test statistics for the long-run *MPC*s are 5.06, 3.92, and 5.30. The critical *F*-value at the 5% level of significance is 3.05 for the partial adjustment and permanent income models. The critical *F*-value at the 5% level of significance is 2.66 for the life-cycle model.

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The Effect of Usage and Size on Tractor Depreciation

Gregory M. Perry, Ahmet Bayaner, and Clair J. Nixon

An econometric model was estimated to explain prices for tractors sold at auction. Tractor age, hours of use, size, and condition were statistically significant explanatory variables. Real tractor depreciation most closely approximated a sum-of-the-years digits pattern. Tractors sold at consignment and bankruptcy auctions brought a lower price than tractors sold by retiring farmers. High levels of usage did not greatly reduce tractor value, but tractors with low annual usage brought substantial premiums in the auction market.

Key words: asymmetric information, auction, Box-Cox, depreciation, tractors.

Economic depreciation of farm machinery is a significant cost of production for most farmers. Defined as the change in the value of a durable asset over a particular time period, economic depreciation is a function of (*a*) physical deterioration and obsolescence, and (*b*) changes in market supply and demand for the asset. Deterioration and obsolescence are influenced by age, use, and care of the asset. A number of studies of economic depreciation suggest depreciation rates can differ greatly among types, sizes, and manufacturers of farm equipment (Peacock and Brake; Leatham and Baker; Perry, Glyer, and Musser; McNeill).

In most of the above-cited studies of economic depreciation, age is assumed to represent the effects of deterioration and obsolescence on equipment values. Although usage levels and tractor size were assumed when developing equipment replacement models, the effect of usage on depreciation was not considered. This paper focuses on the effects of usage, care, and size on tractor depreciation. Significant differences between this and previous studies include use of actual market data and a flexible functional form that allows annual depreciation rates over time to more fully reflect patterns in the data.

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Model Development

The value of a durable asset is the net present value of the stream of expected net returns over its remaining life. Durable capital assets have finite productive lives and are subject to deterioration and obsolescence. Physical deterioration largely reflects the effects of use and care on the asset.[1]

As Keynes noted, the usage level "constitutes one of the links between the present and the future. For in deciding his scale of production an entrepreneur has to exercise a choice between using up his equipment now and preserving it to be used later on" (pp. 69–70). Presumably the entrepreneur will use up equipment in the present if it is more profitable to do so. However, higher levels of usage can be expected to shorten the life of a durable asset, thereby reducing the stream of future returns and the asset's current market value.

Care can moderate the effects of usage. By care, we mean not only the maintenance and repairs regularly performed by the asset owner but also the manner in which the asset is treated.[2] Care can also be considered an economic decision (Parks, Kim). Low levels of care will generally result in higher rates of depreciation.

[1] A durable asset that is never used might also deteriorate over time. However, few capital assets will actually be left idle for long because of high opportunity costs. In most cases, therefore, the major portion of physical deterioration is a function of usage and care.

[2] For example, equipment parked under cover during the winter will probably last longer and maintain a higher market value than equipment left out in the elements.

Obsolescence reflects the rate of technological change over time. If deterioration is fully reflected by usage and care, changes in equipment value with age (at constant usage and care levels) should reflect the effects of obsolescence on asset depreciation. Changes in value over time may also reflect the cost of parts and services provided by the manufacturer.[3] In general, then, a change in equipment age will reduce equipment value.

Most previous estimates of depreciation have focused on specific types of durable assets (such as tractors). These data are often pooled across a number of attributes. Perhaps the most significant attributes for tractors are manufacturer and tractor size (see Reid and Bradford 1983 or Leatham and Baker). The manufacturer embodies a particular level of quality and technology. Consequently, the effects of age and usage could vary among manufacturers.

Larger tractors may experience more intense use than smaller tractors, resulting in more rapid deterioration rates. Obsolescence may also vary across tractor sizes. The relatively larger market for smaller tractors, for example, may cause manufacturers to invest more resources in developing technological advancements for these tractors.

Changing supply and demand conditions also may influence tractor values. Peacock and Brake suggested that net farm income, index of prices received by farmers, index of labor costs, and crop acreage could represent macroeconomic conditions for tractors. Real after-tax interest rates (Hall) and the total stock of tractors might be considered as well.

Data

Studies of depreciation for U.S. tractors have generally relied on dealer resale prices published semi-annually by the National Farm Power and Equipment Dealers Association (NFPEDA). Their *Official Guide* contains summaries of prices received by dealers for used farm tractors of various manufacturers. However, use of equipment dealer sales data in studying depreciation might introduce some bias, since prices may reflect the value of warranties, financing options, and trade-ins. The effects of usage and maintenance are not explicitly reported or estimated by the NFPEDA. Furthermore, a constant depreciation rate is assumed when calculating resale prices for the same model tractor manufactured in different years.

Previous research has relied on average "as-is" prices from the *Official Guide* in their estimation of depreciation patterns. The "as-is" price is calculated by subtracting a reconditioning cost from the dealer's resale price, then reducing the remainder by a percentage of dealer markup. Close inspection suggests that, although prices are reported in nominal terms, a particular tractor model's reconditioning cost is often the same year after year.[4] In addition, the dealer markup is always 20% (pre-1979 tractors) or 15% (1979–present), regardless of the tractor's age, condition or manufacturer. These methods raise questions about the accuracy of NFPEDA data in establishing farm-level tractor values.

An alternative to the *Official Guide* is auction data, which have been available for many years in *Implement and Tractor* (Farm Press Publications, Inc.). Since 1984, Hot Line, Inc. has published the *Farm Equipment Guide,* which contains a monthly series of auction prices paid for farm equipment in different parts of the United States. These transactions are reported by auctioneers and often include price, manufacturer, name, model, year manufactured, condition, hours of use, auction location, auction date, and other descriptive information. This data set was used as the basis for the econometric analysis.

An incomplete data series was available for 1984, so the analysis was limited to 1985 through 1988. The data set was further limited to tractors with greater than eighty horsepower, assuming they are generally used by larger farming operations. Smaller tractors are mostly used by hobby farmers, smaller production-intensive operations (such as orchards) and large operations in secondary uses.

Most previous econometric estimates of tractor depreciation have used remaining value (RV) as the dependent variable. RV is the current price divided by the original purchase price (in current dollars). The RV approach allows prices for tractors of different sizes and attributes to be grouped together in a common data set, thereby providing sufficient degrees of freedom for estimation purposes. List price (as reported in the *Official Guide*) was used as a proxy for sale price in RV calculations because original sale price

[3] It may be difficult, for example, to obtain parts for older tractors, causing their cost to increase.

[4] For example, the reconditioning cost for a 1973 IH Model 1066 tractor was $650 for the 1974–87 period.

was not available. The list price was adjusted for options (e.g., cab, air conditioning, etc.) if the transaction indicated they were present. An index was created to account for changes in the list price level, using average prices paid for two-wheel drive, 110–129 horsepower tractors (USDA). All prices reported in the auction data and their corresponding list prices were converted to 1982 dollars using this index.[5]

The data set was also limited to the seven manufacturers that dominate this portion of the tractor market (designated as companies A, C, D, F, I, M, and W). Tractors manufactured before 1971 were excluded because data for list prices were difficult to obtain. The resulting data set contained 1,030 observations. The data are summarized by manufacturer in table 1.

The RV model can be expressed as

$$RV = f(Usage, Care, Age, Size, Manufacturer, Macroeconomic\ Variables).$$

Tractor hours of use is perhaps the best measure of usage for tractors. Because total tractor hours are highly correlated with tractor age, the usage variable was represented as an annual value (total hours/age). Age was used to account for the effects of obsolescence on *RV*.[6]

No records of care were available from the auction data. However, the auctioneers did report their subjective assessment of each tractor's condition on a scale of 1 (excellent) to four (poor). This condition variable was used as a proxy for care in the model. Tractors in good condition (2) represented the majority (56%) of all observations.

Tractor size was represented by PTO horsepower. An interaction term between horsepower and usage accounted for different intensities of use in larger versus small tractors. A negative sign was hypothesized, suggesting higher usage intensity for larger tractors. An interaction term between age and horsepower reflected different rates of technological obsolescence for different tractor sizes. A positive sign was hypothesized.

Dummy variables represented the seven manufacturers. A set of manufacturer-age interaction terms accounted for any differences in the rate of obsolescence among companies. Manufacturer-usage interaction terms were also included to represent differences in tractor quality among manufacturers.

All macroeconomic variables suggested in the previous section were considered in the analysis. However, because data on total tractor stocks were incomplete, this variable was omitted. The price indexes for labor, prices received by farmers, and total crop acreage were highly correlated with one another and with real net farm income (lagged one year, 1982 price level). Consequently, only real net farm income and real after-tax interest rates were retained in the model.[7]

The auction sales reported in the *Farm Equipment Guide* represent all parts of the United States. Differences in price might occur among regions because of transportation costs and supply/demand relationships. Thus, the United States was divided into six regions: (*a*) Far West, (*b*) Northern Great Plains, (*c*) Southern Great Plains, (*d*) Western Corn Belt, (*e*) Eastern Corn Belt and Northeast, and (*f*) Southeast.

The observations were concentrated in the Western Corn Belt (47%). Each region was represented by a dummy variable, with the Western Corn Belt dummy omitted for estimation pur-

[5] An alternative index could have been created using sale prices of 170–240 horsepower 4-wheel drive tractors. The 110–129 horsepower price series was used because almost 70% of all observations were for tractors with less than 150 horsepower.

[6] Because usage is expressed as an annual rate, it probably does not fully reflect the effects of total usage on *RV*. Consequently, the age variable may capture some of the effects of usage. However, the correlation between total usage and annual usage is .75, suggesting that annual usage probably reflects most of the impact of usage on depreciation.

[7] The after-tax discount rate was calculated using average interest rates charged farmers for machinery loans (Board of Governors of the Federal Reserve System) multiplied by one minus the estimated marginal tax rate (federal and state), then reduced by the implicit GNP deflator (Council of Economic Advisors).

Table 1. Averages of Data and Number of Observations by Manufacturer

	Number of Observations	*RV*	Age (years)	PTO Horsepower	Annual Usage	Condition
Company *A*	64	0.207	8.58	143	268	1.69
Company *C*	90	0.255	7.91	152	290	1.73
Company *F*	17	0.235	10.22	105	308	1.93
Company *D*	512	0.362	8.53	135	361	1.80
Company *I*	277	0.228	8.97	135	309	1.85
Company *M*	34	0.202	10.5	127	264	1.94
Company *W*	26	0.200	10.5	123	222	1.85

poses. Regional parameters were expected to have positive signs because most U.S. tractor manufacturing facilities are located in or near the Western Corn Belt region.

Four types of auctions were represented in the data. Farmers retiring from agriculture (including estate sales), represented 62% of all observations reporting a specific auction type.[8] Also included in the data set were consignment sales (26%), bankruptcies (9%), and dealer closeouts (3%).

Ackerloff argues that used assets will sell at a discount because of asymmetric information about asset quality between buyer and seller. That is, the seller may be disposing of a "lemon" but does not share this information with potential buyers. Consequently, buyers discount their bid price to account for the higher probability of purchasing an inferior good. The consignment and dealer closeout auctions may experience such bias. In contrast, farmer retirement and bankruptcy auctions should generate higher bid prices because the sale is not motivated by liquidating a "lemon."[9] To account for auction type, dummy variables represented each type of auction. The dummy for farm retirement auctions was dropped for estimation purposes. Negative and significant coefficients for consignment and dealer closeout auctions were hypothesized, while an insignificant coefficient for bankruptcy auctions was expected.

Functional forms used in previous econometric estimates of tractor depreciation include linear (Peacock and Brake), exponential (McNeill, Leatham and Baker), and Cobb-Douglas (Reid and Bradford 1983). Choice of a functional form can significantly influence the depreciation pattern. The exponential form, for example, results in a constant depreciation rate. Hulten and Wykoff (1981) suggest use of the Box-Cox flexible functional form when estimating depreciation models because it allows the data to determine the depreciation rate and pattern over time.

The generalized Box-Cox model can be written as

$$\frac{Y^{\lambda}-1}{\lambda} = \alpha_o + \sum_{i=1}^{k} \beta_i \frac{X_i^{\gamma i}-1}{\gamma i} + \epsilon,$$

where λ is the transformation on the dependent variable y, β_i is the regular coefficient for the ith independent variable (X_i), and γ_i is the transformation coefficient for X_i. The Box-Cox can imitate a number of depreciation patterns for durable assets. Assuming X_1 is age, these patterns include linear ($\lambda = 1$, $\gamma_1 = 1$), geometric ($\lambda = 0$, $\gamma_1 = 1$), sum-of-the-year's digits ($\lambda = 0.5$, $\gamma_1 = 1$), and Cobb-Douglas ($\lambda = 0$, $\gamma_1 = 0$). Depreciation rates are, in general, declining over time if $\lambda < 0$ and $\gamma_1 \leq 1$, with increasing rates occurring when $\lambda \geq 0$ and $\gamma_1 > 1$.

The form of the estimated model is

$$\begin{aligned} RV^* = &\sum_{i=1}^{7} \alpha_i M_i + \sum_{i=1}^{7} \beta_i M_i A^* + \sum_{i=8}^{14} \beta_i M_i HPY^* \\ &+ \beta_{15} A^* HWP^* + \beta_{16} HPY^* HWP^* \\ &+ \beta_{17} HWP^* + \beta_{18} NFI + \beta_{19} I + \beta_{20} C \\ &+ \sum_{j=1}^{5} \beta_{20+j} R_j + \sum_{k=1}^{3} \beta_{25+k} T_k, \end{aligned}$$

where

$$RV^* = \frac{RV^{\lambda}-1}{\lambda},\ A^* = \frac{Age^{\theta}-1}{\theta},$$

$$HPY^* = \frac{(Average\ Hours)^{\gamma}-1}{\gamma},$$

$$HWP = \frac{Horsepower^{\phi}-1}{\phi},$$

NFI is real national net farm income (in 1982 \$bill.), I is real after-tax discount rate, C is condition, M_i is dummy variable equal to 1 for the ith manufacturer, R_j is dummy variable equal to 1 for the jth region, and T_k is dummy variable, equal to 1 for the kth auction type. The model was estimated using the SHAZAM econometrics package. Because of the nature of the model, a manual grid search technique was needed to estimate the θ, γ, and ϕ values.

Results and Analysis

The econometric results are reported in table 2. The $\bar{R}^2$ statistic was high given the number of observations and diverse nature of the data. The transformation on RV suggests that a change in any independent nontransformed variable causes a smaller change in RV as RV declines. Thus, real net farm income has less absolute influence on real tractor price as the price declines. The transformations for RV and age suggest the real rate of technological obsolescence most closely exhibited a sum-of-the-years digits pattern.

[8] Auction type was not reported until mid-1986. This percentage was calculated only for data that indicated an auction type.

[9] The condition variable accounts for tractor care; thus, lack of care provided by farmers in some situations (such as bankruptcy) should already be captured in this variable.

Table 2. Econometric Estimates of RV Equation Parameters

Variables	Coefficient	Standard Error
Intercepts by company		
Company *A*	−0.8969*[a]	0.1159
Company *C*	−0.8156*	0.0972
Company *D*	−0.6123*	0.0667
Company *F*	−0.1266	0.1844
Company *I*	−0.8229*	0.0719
Company *M*	−0.8829*	0.1570
Company *W*	−0.6544*	0.2096
Usage variable by company		
Company *A*	−0.0121*	0.0040
Company *C*	−0.0125*	0.0034
Company *D*	−0.0079*	0.0020
Company *F*	−0.0223*	0.0051
Company *I*	−0.0105*	0.0022
Company *M*	−0.0156*	0.0057
Company *W*	−0.0206*	0.0065
Age variable by company		
Company *A*	−0.0409*	0.0064
Company *C*	−0.0347*	0.0062
Company *D*	−0.0413*	0.0036
Company *F*	−0.0822*	0.0117
Company *I*	−0.0415*	0.0041
Company *M*	−0.0251*	0.0104
Company *W*	−0.0464*	0.0133
Horsepower	0.7097E − 05	0.6045E − 05
Age-horsepower interaction	−0.2798E − 05*	0.4991E − 06
Usage-horsepower interaction	−0.1361E − 07	0.2061E − 06
Condition	−0.0723*	0.0068
Net farm income	0.0153*	0.0009
After-tax real interest rate	−0.0079*	0.0033
Auction dummies		
Consignment	−0.0484*	0.0104
Bankruptcy	−0.0521*	0.0158
Dealer closeout	0.0008	0.0277
Regional dummies		
Far West	0.1059*	0.0503
Northern Great Plains	0.0355*	0.0103
Southern Great Plains	0.0116	0.0180
Eastern Corn Belt	−0.0224	0.0134
Southeast	−0.0517*	0.0142
Power transformation for:		
RV	0.41	
Age	0.98	
Usage	0.41	
Horsepower	1.92	
$\bar{R}^2$	0.8032	
N	1030.	
Loglikelihood	687.37	

[a] Asterisk indicates significant at the 95% confidence level.

The company intercept values determine the initial depreciation when a new tractor is sold. The results suggest tractors from companies *A*, *C*, *I*, and *M* experience about the same initial drop in value. Tractors from companies *D* and *W* experience a smaller initial decline. The company *F* intercept is much lower than the other values, suggesting little initial decline in values.

The coefficients for usage were negative and significant for all companies. The company *D* coefficient for usage was much lower, suggesting that their tractors had the highest level of perceived quality during the 1971–88 time period. In contrast, tractors from companies *F* and *W* exhibited large declines in value as annual usage increased.

The coefficients for age were also negative for all companies. Again, changes in age had

the least influence on company *D* tractors and the largest influence on tractors from companies *F* and *W*. These results suggest tractors in the 80+ horsepower range can be grouped into three different categories based on the effects of usage and age. The first is the average group, consisting of tractors manufactured by companies *A*, *C*, *I*, and *M*. The second group, consisting of company *D*, maintains an *RV* above that of the average group at all age and usage levels. The third group, consisting of companies *F* and *W*, have a higher initial value than the average group but depreciate much more rapidly with time and use.

In general, the effects of usage on depreciation were much greater at lower usage levels. This point is illustrated in figure 1.[10] A one-year-old tractor, for example, may have an *RV* of almost 70% at 50 hours of annual usage or 52% at 1,000 hours annual use. The effect of usage on *RV* declines, however, as *RV* becomes smaller.

[10] In calculating figures 2 and 3, it was assumed (unless otherwise noted) that real net farm income was $33 billion (1986 value, 1982 dollars), average real net farm income was $4,665 (1984–86 average 1967 dollars), real after-tax interest rate was 5.5% and that the tractor was a 130-horsepower model manufactured by Company D, in good condition, 300 hours of annual use, and sold in the Western Corn Belt region at a farmer retirement auction.

The horsepower and usage-horsepower interaction coefficients were both insignificant. The age-horsepower interaction coefficient was significant, but the coefficient sign was opposite of that hypothesized. The effect of horsepower on depreciation patterns (where usage and care are held constant) is illustrated in figure 2. Larger tractors had a higher initial *RV* but depreciated (in real terms) much more rapidly than the smaller tractors.

Two alternative hypotheses are posited to explain the more rapid increase in depreciation rates in larger tractors. First, technological change may have proceeded more rapidly in larger tractors. In the early and mid-1970s, large tractors were a relatively new innovation, whereas 100-horsepower, two-wheel drive tractors had been available for more than a decade. The technological inefficiencies embedded into the first generation of larger tractors may have caused heavy discounts in current used tractor markets.

A second hypothesis involves performance reliability. Larger tractors presumably are purchased by farmers with larger operations or limited time for field operations. Downtime costs probably are higher for these farmers. As a tractor ages it generally becomes less reliable, thus diminishing its market value. Smaller tractors,

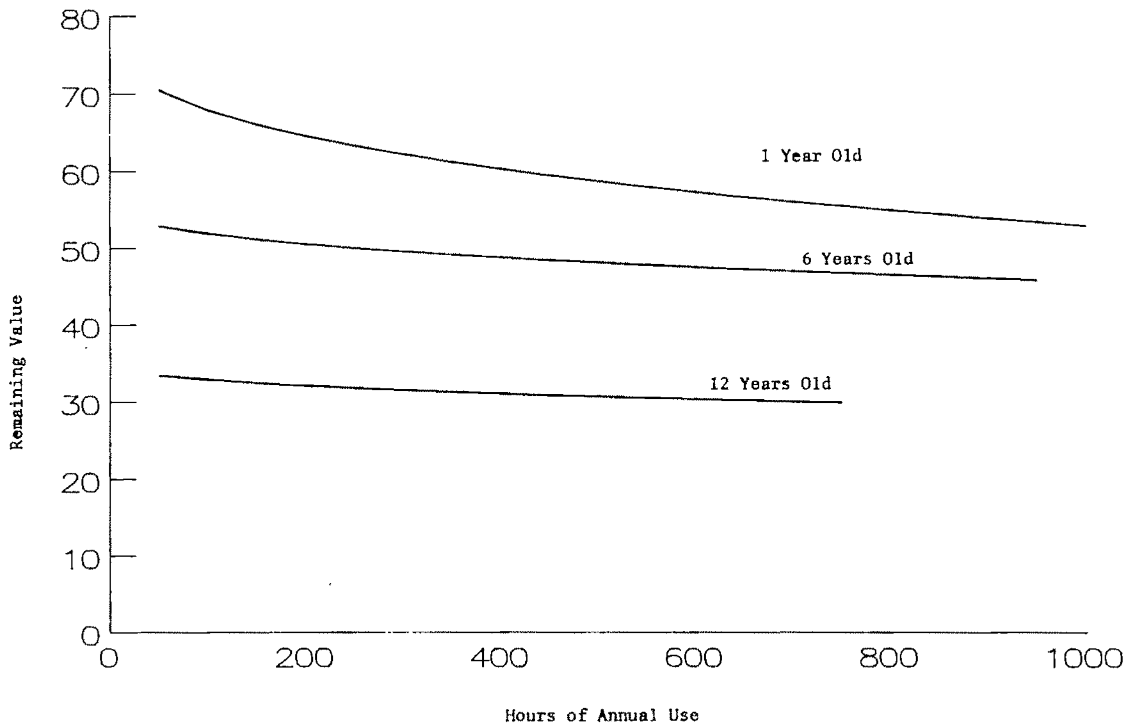

Figure 1. Remaining value for 130 HWP tractor at different use and age levels

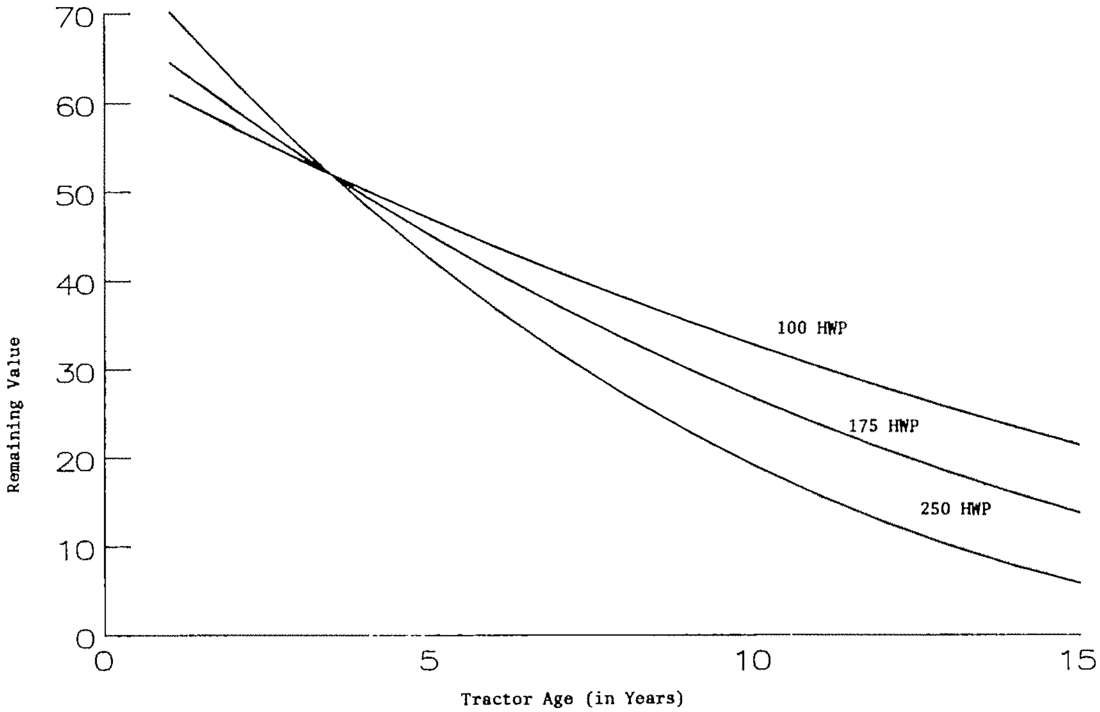

Figure 2. Remaining value by year for different tractor sizes

on the other hand, often perform less critical tasks or are used in smaller operations that are less constrained by tractor capital. Consequently, reliability is less important with smaller tractors and would have less impact on their prices.

Real net farm income had a positive impact on *RV*, consistent with the initial hypothesis. The regional dummy results suggest that tractor prices were lowest in the Southeast and increased as one moved west and north.

The results verified the hypothesis that prices at farmer retirement auctions were higher than consignment and dealer closeout sales, with the difference between consignment and farmer retirement auctions being statistically significant. On the other hand, the bankruptcy dummy coefficient was negative (and significant). Discussions with auctioneers suggest a more complicated auction exists when bankruptcy is involved.

A liquidation bankruptcy auction (Chapter 7) functions much like a retirement auction. In contrast, it is common at a reorganization bankruptcy sale (Chapter 11) for the farmer to attend the auction of his own equipment and bid on those pieces he wants. His neighbors, who often constitute the majority of potential buyers, will not bid against him, out of sympathy or respect. Consequently, the farmer will buy the equipment he wants at a relatively low price.

The results support Ackerloff's argument that uncertainty about why a piece of equipment is being sold may cause buyers to bid less than the equipment's perceived value. The asymmetric information argument does not, however, totally explain why tractors drop in value so rapidly when first purchased. For example, a new 130-horsepower tractor with no hours on it would have an *RV* of 90.5 if sold at a farmer retirement auction and 86.0 if sold on consignment.[11] The same tractor sold after 100 hours of use would generate an *RV* of 78.8 if sold in a farmer retirement auction. Perhaps the expiration of free dealer services (such as those in warranties) may account for this large drop in value.

Figure 3 provides a comparison of annual depreciation rates over a ten-year period for this model versus four other models.[12] The other models were estimated and (or) reported by Reid and Bradford (RB), Leatham and Baker (LB), Peacock and Brake (PB) and the *Agricultural Engineering Yearbook* (ASAE). Two versions

[11] An *RV* of 90.5 for a new tractor suggests list prices may be higher than actual sale prices.

[12] The depreciation rate is calculated as

$$Rate = \frac{|RV_{t-1} - RV_t|}{RV_{t-1}}.$$

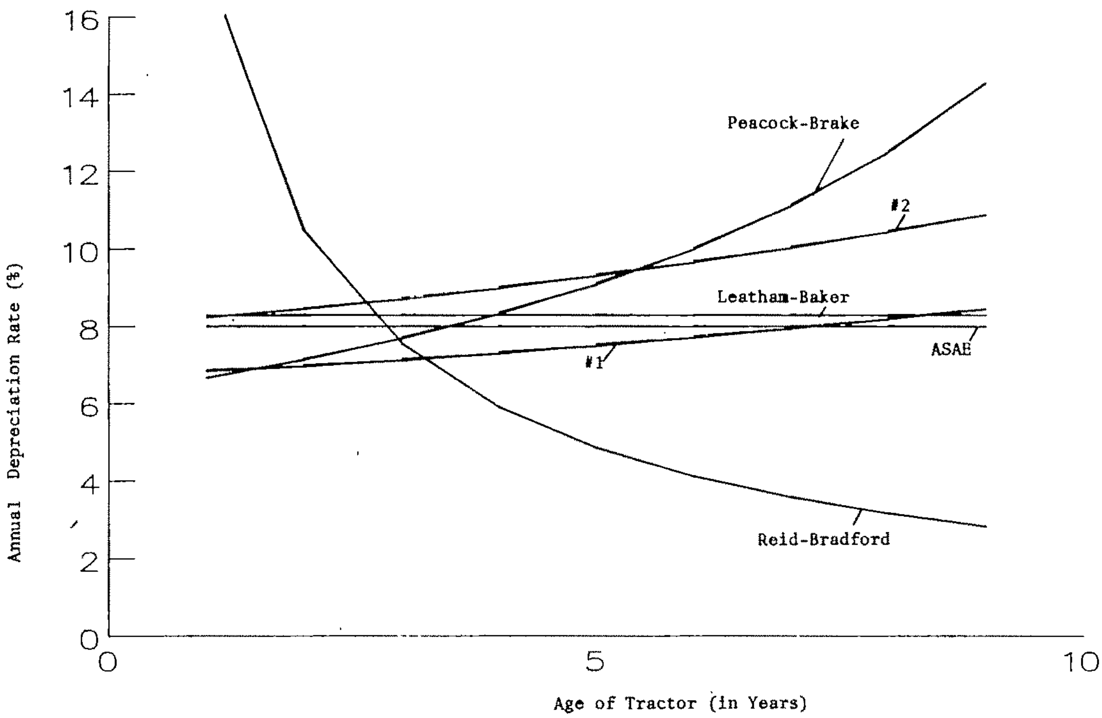

Figure 3. Annual depreciation rates for different remaining value models for tractors

of the auction data model are given in the figure. The base case (designated as number one) presumes annual usage and condition remain constant during the ten-year period. An alternative situation (designated as number two) also has a constant usage level, but allows condition to begin at 1.0 and increase by 0.2 units per year.

Both versions of the model exhibited depreciation patterns that were in between the ASAE-LB models and the PB model. This pattern is consistent with the flexible functional form estimated for the data. The RB model exhibited a substantially different depreciation pattern, due in part to their choice of functional form.

A decline in condition accelerated the depreciation rate by about 2% per year. Condition generally declines over time, so number two may more correctly reflect annual depreciation rates. Offsetting a decline in condition, however, would be a decline in the annual usage level. Average usage remained at about the same level in the data during the first ten years of tractor life and then declined.[13]

[13] Usage patterns in the data make it difficult to make general statements about how individual usage patterns vary over a tractor's life. A more or less level usage pattern in the data suggests usage does decline over time because crop acreage has been on a steady decline during most of this decade.

Concluding Comments

This paper focused on the influence of usage and size on tractor values. A remaining value equation was estimated for tractors sold in auctions during the 1985–88 period. Both usage and horsepower were significant variables in explaining changes in tractor price. Differences in tractor prices were also evident between companies, regions of the United States, and types of auctions. Above-average levels of usage did not result in large discounts in tractor price, but low-average usage did generate substantial premiums. Larger tractors depreciated more rapidly than their smaller counterparts. The type of auction sale was also influential on auction price.

A logical next step in this analysis would be to use the *RV* equation in identifying optimal equipment replacement patterns for tractors. Given the effect of different *RV* equations on optimal replacement and the differences in depreciation patterns demonstrated in figure 3, one might expect that this new *RV* model will identify replacement patterns that differ from those identified by other researchers.

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A Prospective Assessment of the Impacts of Bovine Somatotropin: A Case Study of Wisconsin

Bruce W. Marion and Robert L. Wills

The predicted effects of bST on aggregate supply, milk price, and farm structure is extremely sensitive to several key assumptions: the impact of bST on production per cow, cost of bST to farmers, returns required by farmers to adopt bST, price of milk when bST is introduced, speed and extent of adoption. A case study of Wisconsin dairy farms indicates that the overall economic impact of bST will be much less than most other studies have predicted. The projected effects, however, are similar to Cochrane's treadmill theory, albeit less severe than predicted by earlier estimates.

Key words: biotechnology, bST, *ex ante* assessment, new technology, socioeconomic impact.

Prospective assessments of new technologies are difficult and need to be judged by different standards than after-the-fact assessments (Fishel). Benefits and costs of future technologies are uncertain. Moreover, the speed and extent of adoption are unknown. However, social scientists are increasingly asked to make social and economic assessments of technologies prior to their commercial introduction. Although such assessments may require wide confidence intervals, they still can provide useful insights to policy makers, potential adopters, and interested parties (for a different approach, see Lemieux and Wohlgenant). A well-developed model can be used to examine the sensitivity of results to various assumptions and can be updated as more information becomes available.

Of the many biotechnology products potentially affecting agriculture, probably none has received greater attention than bovine Somatotropin (bST). Prospective economic assessments of the impacts of bST can focus on individual farms, on aggregate prices and quantities, and measures of economic welfare. The 1987 study by the U.S. Department of Agriculture's Economic Research Service (Fallert et al.) is the most ambitious effort to model both the micro and macro impacts of bST. The USDA linked Westcott's simulation model of the dairy industry to farm-level simulation models of representative dairy farms in different regions. While the results of this study are of considerable interest, they are sensitive to assumptions concerning (*a*) the production response to bST; (*b*) the returns required by farmers to adopt bST; (*c*) the price that farmers will have to pay for bST; (*d*) the price of milk when bST is introduced; and (*e*) the speed and extent of adoption.

Other studies have provided prospective assessments of the economic impact of bST using different sets of assumptions (Kalter et al.; Boehlje, Cole, and English; Magrath and Tauer; Kalter and Milligan; Yonker, Knutson, and Richardson; Butler and Carter; Marion, Wills, and Butler). The research reported here examines the impact of varying the assumptions for the above five factors, using Wisconsin dairy farms as a case study.

Farm Decision Model

Most previous analyses of the farm level profitability of bST have used simulation models of representative dairy farms. A similar but more transparent farm enterprise model is employed in this study to determine the economic feasi-

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bility of bST by comparing incremental revenues and incremental costs. Incremental revenue and costs were defined as:

incremental revenue from bST = % production response to bST * original production per cow * milk price

incremental costs plus returns to management = cost of bST + increased feed costs + increased hauling costs + increase in other variable costs + required return to management.

For some variables, a wide range of values is plausible. Because these variables drive the rest of the analysis and are the major reason why the results differ from previous analyses, they warrant comment.

Impact of bST on Production Per Cow

A critical question is whether bST will provide a proportional (e.g., 10%) or constant (e.g., 8 lbs.) increase in milk production, or a partly constant and partly proportional increase. Fallert et al. assumed an 8.4-pound increase per cow per day regardless of production per cow, whereas Kalter et al. examined proportional responses ranging from 6.4% to 25.6% per year. If a constant increase is assumed, bST tends to be economically feasible for all cows (and herds) or for none. If a proportional response is assumed, bST may be economically feasible on high producing cows but not on low producing cows.

Research by dairy scientists presents a mixed picture. Given the same level of management, most of the research points toward a constant response from cows of differing genetic capability. However, much of the difference in production per cow of commercial dairy farms within a state or region is attributable to differences in management. And there is a strong consensus that poor management will severely restrain the production response to bST.[1] Thus, to the extent that production per cow reflects the level of management, the response to bST is likely to be greater in high-producing herds than in low-producing herds.

The level of response under field conditions is also uncertain. Recent research suggests a daily increase in production of 17% to 25% for well-fed and well-managed cows. This translates to a 10.5% to 15.5% increase in annual production because bST is not administered until about the ninetieth day of lactation. Under field conditions the response to bST ranges from zero for poorly managed herds to results comparable to experimental results for very well-managed herds. Fallert et al. estimated that the response under field conditions would average 25% less than under experimental conditions.

Some evidence exists that first calf heifers may respond less than older cows (current research by University of Wisconsin dairy scientists), while other research shows little difference in response. Uncertainties also exist about the response rate to bST in the second, third, or later years of administering bST. In short, much remains unknown about the production effects of bST. Given these uncertainties, sensitivity analysis is appropriate. In the research reported here, we examine three levels of proportional responses (9%, 12%, and 15%), a response that is partly constant and partly proportional (900 lbs. + 6% of base production), and a totally constant response (1,800 lbs./year).

Cost of bST to Farmers

Most studies have either ignored bST cost, assumed a certain price, or determined bST price as a residual. Lesser, Magrath, and Kalter used a bST price of 17¢ per cow per day in the fictional ad sent to New York farmers to determine their attitudes toward adoption. Fallert et al. assumed that farmers will require a return to management that is twice the cost of the drug in order to use bST. With an 8.4 pounds per cow per day response to bST and 1986 price levels, they found that representative U.S. dairy farmers could pay 24¢ per cow per day and still achieve the required two for one return. Several studies assume that bST will be sufficiently profitable for farmers so that the price of bST will not con-

[1] This section relies on conversations with dairy scientists Dale Bauman, Cornell University, and Dave Combs, University of Wisconsin-Madison. Bauman, one of the leading researchers of bST, believes the response to bST will be at least partly proportional to base production per cow. However, we also acknowledge the point made by one of our reviewers: "The assumption of differences in production per cow being attributable to differences in management might hold within a state but might not hold across states and regions where such factors as quality of forage and weather may be strong factors."

strain its adoption. This assumption may stem, in part, from estimates that the cost of producing bST will be 8.5¢ to 18.6¢ per daily dose (Kalter et al.) and assumptions that bST will be priced near its cost of production. Improvements in technology since Kalter's study have dropped expected bST production costs even further to 5¢ or less per daily dose.

However, the cost of producing bST may have little bearing on the price charged to farmers. The costs of marketing bST could dwarf production costs. In addition, bST manufacturers have substantial research and development sunk costs on which they hope to realize a return. Thus, bST manufacturers will have a strong financial incentive to price bST substantially above production costs.

The likely structure of the industry will allow some form of price leadership and/or coordinated pricing. Only four pharmaceutical companies are currently in the worldwide race to market bST. Two of these have a significant lead. And, large economies of scale in the production of bST indicate that entry barriers will be high. Some bST manufacturers expect to serve the world market from a single plant. Although the initial pricing strategies of these companies are difficult to predict, the high degree of oligopolistic interdependence will encourage some type of coordinated pricing.

Below, the manufacturers' profit-maximizing prices are calculated under different assumptions. In the sensitivity analysis, bST prices are allowed to range from 25¢ to 40¢ per dose.

Returns to Management Required by Farmers to Adopt bST

Most studies have not incorporated a threshold return to farmers who adopt bST as a payment for management and risk. However, farmers are unlikely to adopt bST unless at the time of adoption, they perceive an acceptable return after costs for their management and risk. Pharmaceutical companies estimate that "farmers will not likely adopt bST unless they can obtain a $2 net return for each $1 in bST purchase cost" (Fallert et al., p. 8). The logic of this estimate is questionable. Since bST will be a variable cost of production, not a capital investment, we see no reason why the net returns required by farmers for adopting bST should vary proportionally with the price of bST.

Of those responding to a survey in mid-1987 of Wisconsin dairy farmers, 36% said they would require 50¢ or less profit per cow per day of bST use, 35% would need $.51 to $1.00 per cow per day of bST use, and 29% would require over $1.00 per cow per day of bST use (Nowak and Barnes). Given the paucity of farmers' information about bST at the time of the survey, their responses are at best a rough estimate of the returns required for adoption.

These daily farmer returns can be translated into annual returns. If bST is administered for 215 days, annual returns to an owner of a fifty-cow herd corresponding to 20¢, 30¢, 40¢, and 50¢ return per cow per day are:

Return/Cow/Day of bST Use	Annual Return in 50 Cow Herd
$.20	$2,150.00
.30	3,225.00
.40	4,300.00
.50	5,375.00

If administering bST is relatively easy, as appears likely, and if the management requirements are not too high—a point on which we have little knowledge—an additional $2,000–$4,000 may be a reasonable incentive to adopt bST. In this analysis, farm returns range from 20¢ to 40¢ per cow per day. Manufacturers of bST will have strong incentives to make bST as easy to use and manage as possible. Because at least some of the management changes needed to effectively use bST will involve front-end investments in human capital or management systems, operators of small herds may require a higher return per cow per day to adopt bST than operators of large herds.

Milk Prices

Milk prices have dropped substantially in recent years and may drop even further by the time bST is introduced in late 1989 or in 1990. Whereas Kalter et al. used an all-milk price of $12.69 per hundredweight (cwt.) and Fallert et al. used an initial price of $12.52 in estimating bST profitability, Wisconsin dairy economists expect the Wisconsin all-milk price will be approximately $11.00 per hundredweight by 1990. In this analysis, we use a milk price of $11.00 or allow prices to range from $10.00 to $11.50 per hundredweight.

Increase in Feed Costs

Higher producing cows require more feed. The increase in feed costs required per hundredweight increase in milk production from bST

appears to be similar to the general relationship between feed costs and milk production. We use two linear equations to estimate feed costs, both drawn from Wisconsin Farm Enterprise Budgets (Luening et al.): (*a*) annual feed cost per cow = $201.38 + .0289 pounds of milk per year; and (*b*) annual feed cost per cow = $274.00 + .034 pounds of milk per year.[2]

Equation (*a*) has "typical" hay and concentrate prices and is used in most of our calculations. Equation (*b*) reflects higher feed costs and is used for sensitivity analysis.

Increase in Hauling and Other Variable Costs

Increased milk production from bST will likely increase the variable costs of milk hauling, farm labor, power, breeding, and veterinary services. The average cost to farmers of hauling milk in Wisconsin is currently about 20¢ per hundredweight. There is no research on the additional labor, veterinary, breeding, and power expenses associated with bST usage. Wisconsin Farm Enterprise Budgets (Luening et al.) indicate that as annual production per cow increases 100 pounds, these expenses increase 67¢. Based upon these figures, hauling and other variable costs are assumed to increase by 87¢ per hundredweight for milk increases resulting from bST. We also examine the effect of a lower increase in variable costs (.20 + .335 = .54/cwt.) The example in table 1 shows how the farm decision model works.

Given the assumed values, incremental revenues exceed incremental costs plus the return to management. BST would be economically feasible on cows producing somewhat less than 16,000 pounds of milk per year. The break-even production per cow changes significantly for different responses to bST, different milk prices and different bST prices plus farm return (table 2).

Table 1. Illustration of Farm Decision Model for bST, Wisconsin, 1990

Incremental Revenue Assumptions:	
Milk price in $/cwt.	$11.00
Annual production per cow without bST	16,000 lbs.
% annual response to bST	12%
Calculations:	
Incremental milk production:	
160.0 * .12 =	19.2 cwt.
Incremental revenue:	
19.2 cwt. * $11.00 =	$211.20
Incremental Cost Assumptions:	
bST price/cow/day	.30
Increased returns to farm mgt./cow/day	.30
Milk hauling costs/cwt.	.20
Labor, power, breeding, & vet. costs/cwt.	.67
Feed cost increase per cwt.	2.89
Calculations:	
bST price: $.30 * 215 days use/cow	64.50
Returns to mgt.: $.30 * 215 days	64.50
Milk hauling: $.20 * 19.2 cwt.	3.84
Other variable costs: $.67 * 19.2 cwt.	12.86
Increased feed costs: 2.89 * 19.2 cwt.	55.49
Total incremental costs	$201.19

Distribution of Wisconsin Herds by Average Production Per Cow

If the response to bST is at least partially proportional to the production per cow, then the distribution of cows by level of output becomes important in estimating the potential use of bST. Data on the distribution of Wisconsin herds by level of production are from a survey of 1,163 herds (63,164 cows) conducted by the Wisconsin Agricultural Statistics Services (WASS) in January 1989.

The monthly sample distribution was expanded to derive a population distribution for Wisconsin dairy cows.[3] This estimated distribution of cows by level of production is used in the following sections to calculate the number of cows on which bST will be economically feasible under various conditions, and the increase in state milk production that may occur as a result of bST.

Potential Demand for bST

The impact of bST on state and national milk production depends upon the extent and speed of its adoption and the production response to bST. Several other studies have concluded that bST will be widely and quickly adopted, at least in part because they have assumed it will be

[2] Fallert et al. used the following equation to estimate feed costs in the Lake States:

Feed costs = $156.18 + .0271 lbs. of milk/year.

For a cow producing 16,000 lbs. of milk, feed costs estimated by Fallert et al. are $75 less than Luening et al. The forage costs estimated by Fallert et al. appear to be substantially underestimated.

[3] Annual sample 1989 milk production was calculated by dividing January 1989 values by .0813, the average proportion of annual milk production accounted for by January milk production for 1977–86. The percent of cows in each production category was applied to the total January 1989 Wisconsin dairy cow inventory of 1,730,000 to derive state values.

Table 2. Production per Cow at Which bST Use Is Feasible Under Different Economic Conditions

Milk Price/cwt.	bST Price Plus Farm Return		
($)	.50	.60	.70
A. 15% Response to bST			
10.00	11,486	13,783	16,080
10.50	10,634	12,761	14,887
11.00	9,899	11,879	13,859
11.50	9,260	11,112	12,964
B. 12% Response to bST			
10.00	14,357	17,229	20,100
10.50	13,292	15,951	18,609
11.00	12,374	14,849	17,324
11.50	11,575	13,890	16,205
C. 9% Response to bST			
10.00	19,143	22,972	26,800
10.50	17,723	21,268	24,812
11.00	16,499	19,799	23,099
11.50	15,433	18,520	21,606
D. 900# + 6% Response to bST			
10.00	13,715	19,458	25,201
10.50	11,585	16,901	22,218
11.00	9,748	14,698	19,648
11.50	8,150	12,780	17,410
E. 1800# Response to bST			
10.00	All cows	None	None
10.50	All cows	None	None
11.00	All cows	All cows	None
11.50	All cows	All cows	None

profitable on most cows and for most farmers. Lesser, Magrath, and Kalter estimated that bST would be used on 63% to 85% of New York cows within three years of commercialization, based upon a survey of 173 farmers in 1984. Nowak and Barnes indicated 13% of Wisconsin's dairy farmers would be early adopters of bST, 31% were unlikely to adopt, and the remaining 56% would fall in-between, based upon a survey of 270 farmers in 1987. A major limitation of these surveys is that farmers were asked to respond to a hypothetical set of facts that may or may not exist when bST is introduced.

In our analysis, we first examine the extent to which bST is economically feasible for Wisconsin cows under various assumptions. Using the incremental revenue-cost model and the distribution of Wisconsin herds by production level, we estimated the potential demand for bST. Table 3 presents two bST responses: (*a*) a 12% proportional response and (*b*) a partly fixed (900 lbs./year) and partly proportional (6%) response. In the example, the Wisconsin all-milk price is $11.00 per hundredweight and returns to management are 20¢, 30¢, or 40¢ per cow per day. The price of bST is varied from 20¢ to 50¢ per daily dose.

In order to estimate the contribution to manufacturer development costs and profits, we assume that the production and marketing costs of

Table 3. Potential Demand for bST in 1989 and Manufacturer Contributions to Profits with Different bST Prices and Returns to Farmers, State of Wisconsin

bST Price/ Cow/Day	Returns to Farmers for Using bST	Number of Wisconsin Cows on Which bST Is Feasible		Potential Contributions to Manufacturer Development Costs and Profits per Day if Cost to Produce bST = $.10	
		Response to bST: 12%	900# + 6%	12%	900# + 6%
A. .50	.20	753,722	513,623	301,489	205,449
.45	.20	973,208	925,330	340,623	323,866
.40	.20	1,140,969	1,222,669	342,291	366,800
.35	.20	1,279,754	1,441,861	319,938	360,465
.30	.20	1,406,952	1,571,950	281,390	314,390
.20	.20	1,570,777	1,697,654	157,078	169,765
B. .50	.30	355,642	66,355	142,257	26,542
.40	.30	753,722	513,623	226,117	154,087
.35	.30	973,208	925,330	243,302	231,332
.30	.30	1,140,969	1,222,669	228,194	244,534
.25	.30	1,279,754	1,441,861	191,963	216,279
.20	.30	1,406,952	1,571,950	140,695	157,195
C. .50	.40	119,400	13,492	47,760	5,397
.40	.40	355,642	66,355	106,693	19,906
.35	.40	530,224	218,220	132,556	54,555
.30	.40	753,722	513,623	150,744	102,725
.25	.40	973,208	925,330	145,981	138,800
.20	.40	1,140,969	1,222,669	114,097	122,267

Note: Assumptions—Wisconsin all-milk price = $11.00 per cwt.

bST manufacturers will be 10¢ per daily dose. Increasing or decreasing the cost of bST does not alter the profit-maximizing price shown in table 3.

The joint profit-maximizing price for manufacturers ranges from 25¢ to 40¢ per daily dose under the conditions assumed in table 3. Thus, if there is sufficient discipline among bST manufacturers to achieve a joint profit-maximizing equilibrium, the equilibrium price will likely fall in that range. If one or more companies choose a low price strategy in hopes of developing a dominant market share, bST could be priced much closer to production costs, at least for a while.

Small changes in either bST price or farm returns substantially change the number of Wisconsin cows on which bST is feasible and the contribution to manufacturer profits. In much of the analysis that follows, bST price and farm returns are combined to reflect the trade-off shown in table 3. Manufacturer profits in Wisconsin are maximized when the combined value of bST price and farm return is in the range of 50¢ to 70¢ per cow per day.

Sensitivity of Results

The previous sections have provided some indication of the effects of varying the assumed values of the four key variables: production response to bST, milk price, bST price and the return required by farmers to adopt bST. Figures 1 and 2 are analogous to potential demand curves for bST under different economic conditions. Figure 1 holds milk price at $11.00 per hundredweight and examines the effects of four bST response rates on the number of Wisconsin cows on which bST is economically feasible. Figure 2 assumes a 12% annual response to bST and examines the effects of three milk prices.

We are particularly interested in the potential demand for bST when the price of bST plus farm returns is between 50¢ and 70¢ per cow per day. In that range, the economic feasibility of bST is very sensitive to the values of key variables.

The sensitivity of the results to changes in feed and other variable costs also was examined. The impact of varying these two costs is shown be-

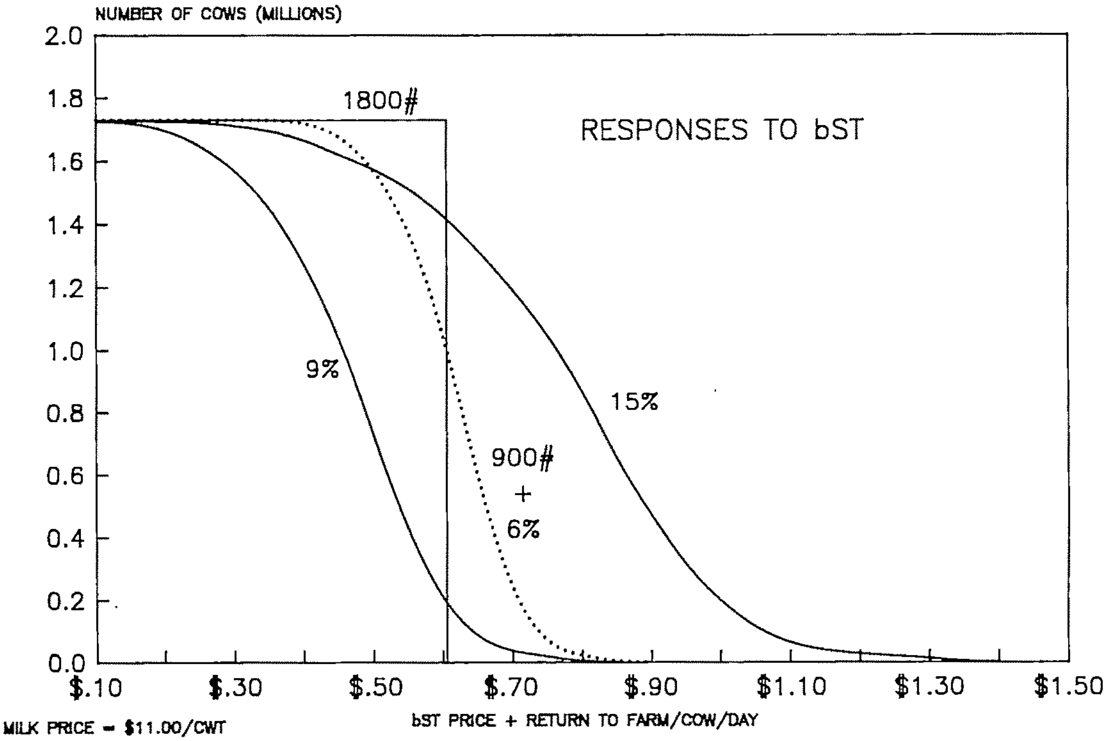

Figure 1. Estimated number of Wisconsin cows in 1989 on which bST will be economically feasible with different responses to bST

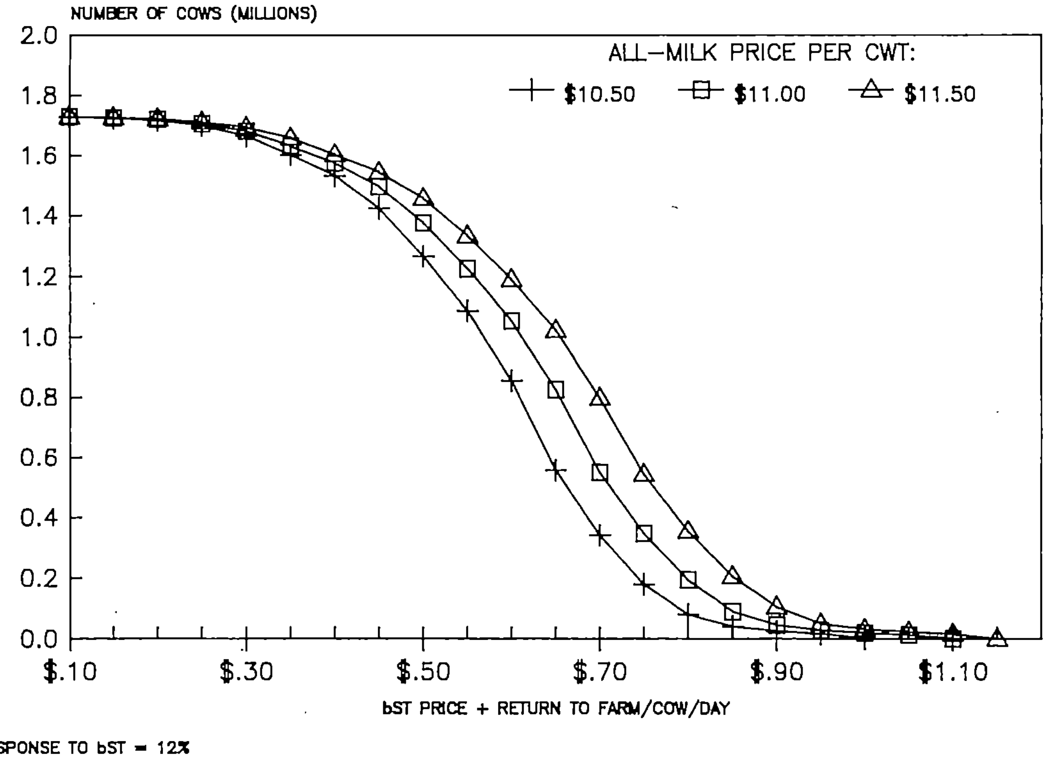

Figure 2. Estimated number of Wisconsin cows in 1989 on which bST will be economically feasible with different all-milk prices

low.[4] The first combination, normal feed prices and full variable costs, is used in all the other analyses in this paper.

Feed Prices	Other Variable Costs	Break-Even Production/ Cow	No. of Cows on Which bST Is Economical
a. Normal	.87/cwt	14,849	1,052,805
b. High	.87/cwt	15,973	850,109
c. Normal	.54/cwt	14,202	1,147,025

The results are relatively insensitive to changes in other variable costs (hauling, labor, veterinarian, breeding, and power). Using high rather than normal feed prices shifts the results in about the same magnitude as a 50¢ drop in milk prices.

Impact of bST on State Milk Production

Figure 3 indicates the percentage increase in state milk production that would occur in 1989 with different bST response rates if bST were given to all cows on which it is economically feasible and the all-milk price were $11.00. For bST price plus farm return of 50¢ to 70¢ per cow per day, the potential increase in state production ranges from roughly 1% to 14%, depending on the production response to bST.

Given the uncertainties about the response to bST, the price of bST and other factors, we developed lower and upper estimates of the percentage of cows on which bST will be economically feasible and the increase in state production that would occur if bST were given to all cows on which it is economically feasible (table 4). However, universal adoption by all farmers with feasible opportunities is unlikely. Enrollment experience with DHI suggests that bST might not be used on more than 45% of the state's cows, at least during the first few years of commercial use. That level of bST utilization would increase state milk production 4.9% to 6.5%, given the assumptions for table 4.

Impact of bST on Milk Prices

Increased milk supply due to bST is one of many factors that will influence future milk prices. We

[4] Other variable values are set as follows: bST response—12%; milk price—$11.00/cwt; bST price plus farm return—$.60/cow/day.

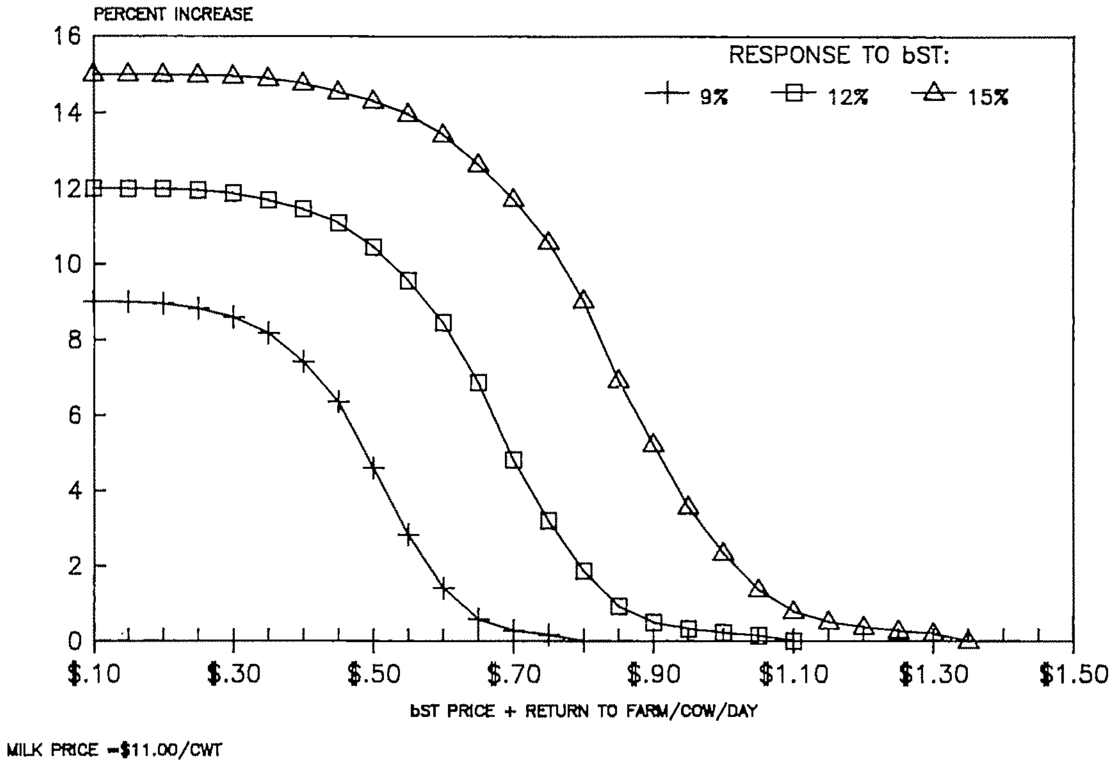

Figure 3. Percent increase in Wisconsin milk production with three different bST response rates, circa 1989

consider here only the incremental impact of bST on milk prices and assume that adoption rates of bST nationally will be similar to Wisconsin.

The estimated impact of bST on milk prices depends upon the federal dairy program in place during 1990–95. If the next farm bill continues the current program, federal support prices for manufactured grade milk can drop 50¢ per hundredweight in any year in which government purchases of dairy products are expected to exceed 5 billion pounds. Under this scenario, it seems reasonable to project a 50¢ per hundredweight decline in milk prices for every 5 billion pound increase in U.S. milk production attributable to bST. If U.S. milk production in 1990 without bST is about 155 billion pounds an-

Table 4. Upper and Lower Estimates of Percent of Wisconsin Cows on Which bST Will Be Economically Feasible in 1990

	Lower Estimate[a]		Upper Estimate[b]	
bST Price Plus Farm Return per Cow per Day	% of Cows on Which bST Is Feasible	% Increase in State Milk Production	% of Cows on Which bST Is Feasible	% Increase in State Milk Production
.40	56	5.9	92	11.5
.45	32	3.7	88	11.2
.50	15	1.8	83	10.8
.55	5	0.7	75	10.0
.60	2	0.3	66	9.1
.65	1	0.2	55	7.8
.70			41	6.0
.75			28	4.3

[a] bST response rate of 9%, all-milk price of $10.50/cwt., higher feed costs and full variable costs.
[b] bST response rate of 12%, all-milk price of $11.00/cwt., normal feed costs and lower variable costs.

nually, a 3.3% increase due to bST would lead to a 5 billion pound expansion in supply. In Wisconsin, the use of bST on the top one-fourth of the state's cows will increase state production about 3.3%. We believe it will take two or three years to achieve that level of adoption. If a similar scenario occurs nationally, milk prices would drop 50¢ per hundredweight at that point. An additional 50¢ decline could eventually be triggered.

The above analysis assumes that the present dairy program continues. An alternative dairy policy could allow prices to respond fully to market forces. With farm-level price elasticity of demand for milk of roughly −0.3, a 3% expansion in supply would lead to a 10% decline in milk prices, or roughly $1.10 per hundredweight. Thus, a free market for milk would result in bST having about double the price depressing effects as the current dairy program.

By comparison, Fallert et al. estimated a support price under the current dairy program of $9.60 per hundredweight in 1990 before bST is introduced (equivalent to Wisconsin all-milk price of about $10.25). Without bST, no further reductions in price supports would be required according to USDA simulation models. With bST, the USDA results indicated price supports would drop to $9.10 per hundredweight in 1991 and to $8.60 per hundredweight in 1992. This is a much sharper reduction in milk prices than we project, in part because Fallert et al. assumed a rapid rate of adoption and also because they assumed bST will be economically feasible for most dairy herds.

Effect of bST on the Structure of Wisconsin Dairy Farms

One of the issues surrounding bST is its likely effect on the economic viability of different size farms. Research to date indicates that adopting bST will not require large herds. However, effective use of bST will require careful management and may be more economically feasible on high-producing cows. Data on production per cow in Wisconsin indicate that herds with forty or fewer cows generally have lower production per cow than larger herds. A positive relationship between herd size and production per cow occurs with herds up to forty-five to fifty cows (table 5). For all herd sizes, substantial variation exists in the average production per cow.

Table 5 shows the proportion of Wisconsin herds in each size class in 1989 that had average herd production greater than several production levels. Regardless of the production level at which bST is economically feasible, herds with forty or fewer cows are less likely to find it economically attractive. The introduction of bST will place added financial pressure on farms with low producing herds for two reasons: First, such operators are less likely to find bST use profitable.[5] Second, adoption of bST by farmers with high producing herds is likely to lead to lower milk prices. On average, herds with fifty or more

[5] Of course, the financial pressures are a matter of degree. Farms that are far below the break-even production level will be at a greater disadvantage than those close to the break-even level. At the break-even level, farmers are indifferent between the returns they receive without bST and the returns, including compensation for administering bST, that they receive if they use it.

Table 5. Percent of Herds with Average Production Exceeding Various Production Levels by Herd Size, 1989 WASS Sample

Herd Size (No. of Cows)	No. of Sample Herds	Herd Average Production Per Cow/Year	Percent Exceeding Various Production Levels		
			12,000	16,000	20,000
1–10	19	11,022	31.6	15.8	5.3
11–20	81	11,901	44.4	18.5	6.2
21–30	158	12,599	56.3	22.2	3.8
31–40	235	13,899	68.5	30.6	6.4
41–50	202	15,272	81.2	46.5	9.4
51–60	152	15,934	87.5	50.0	13.8
61–70	84	15,787	84.5	51.2	9.5
71–80	69	16,387	89.9	55.1	11.6
81–90	29	16,437	89.7	58.6	10.3
91–100	30	16,429	86.7	63.3	16.7
101–150	74	15,936	89.2	50.0	8.1
>150	30	17,128	93.3	76.7	16.7
Total or Mean	1,163	14,666	74.6	40.6	8.8

Source: Wisconsin Agricultural Statistics Service

cows do not appear to be at a disadvantage relative to larger herds. BST will provide an added incentive for farmers to increase the productivity of their cows and improve their management practices in order to take advantage of the new technology.

Conclusions

Most of the previous prospective assessments of bST have concluded that bST will be profitable for most U.S. dairy farmers. However, these studies have assumed values for several key variables that may not exist when bST is introduced. Our analysis indicates that the economic feasibility and likely adoption of bST will be very sensitive to (*a*) the production response to bST, (*b*) milk prices, (*c*) the price that farmers will have to pay for bST, and (*d*) the returns required by farmers to adopt bST.

Based upon our analyses, we expect a more gradual and less extensive adoption of bST and a more modest impact on milk production and milk prices than most earlier studies. The economic impact of bST will still be significant, however. Our estimates indicate that if bST is used by one-fourth of U.S. cows (assuming a similar distribution of production/cow as in Wisconsin), milk supplies will increase enough to trigger a milk price decline of 50¢ per hundredweight (assuming continuation of the current dairy program). The three-fourths of Wisconsin herds that have not yet adopted bST will suffer a decline in net income of roughly $100 million per year. The one-fourth of the state's herds that are early adopters of bST will increase their net incomes during the period before milk prices decline. After the price drop, these farmers will find their net incomes are about the same as before bST was introduced. The projected effects echo Cochrane's comment that "technological advance puts farms on a treadmill" (Cochrane, p. 66). Other businesses and consumers will benefit to some extent (see Marion, Wills, and Butler for a fuller discussion).

Although our analysis is considered to employ more realistic assumptions than most previous studies of bST, the more important point is that the results of such studies, including this one, are very sensitive to the underlying assumptions. Given the speculative nature of all prospective assessments, greater emphasis on sensitivity analysis is warranted.

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The Decision to Double Crop: An Application of Expected Utility Theory Using Stein's Theorem

Michele C. Marra and Gerald A. Carlson

A nonlinear, single-equation acreage allocation model derived from expected utility theory using Stein's theorem for covariance decomposition is developed. This decomposition allows the covariance of utility parameters and revenues to be expressed in terms of measurable variables. The model is applied to state-level data to estimate the relative importance of various economic factors in determining the pattern of double cropping wheat and soybeans in the southeastern United States. The hypothesis that the riskiness of returns is important in the aggregate is rejected for some of the states, although the constrained expected utility model without the effect of risk performs better than a standard wheat acreage response model.

Key words: double cropping, risk, risk attitudes, Stein's Theorem.

Small grain (primarily soft red winter wheat) production followed by soybeans is a multi-cropping system becoming widely used in the Southeast (Gallaher). This system, usually referred to as double cropping, has increased generally in the past fifteen years, and as much as 40% of planted soybeans are in this system in some years. However, it has neither advanced steadily like many agricultural innovations nor proceeded at the same rate in all states in the Southeast. From 1976 to 1979 and again in the mid-1980s double-cropped soybeans as a proportion of total soybean acreage decreased in general in the Southeast (Marra and Carlson).

Double-cropped soybeans are usually planted thirty to fifty days later than full-season soybeans and harvested at the same time. They generally are expected to have lower average yield and more yield variability than full-season soybeans.[1] They may require more management input and pesticides, but extra income from a wheat crop may offset the lower and riskier total revenue from the late-planted soybean crop.[2] Also, the income-stabilizing possibilities of growing two commodities with offsetting price movements and reduced technical risk from a mixed temporal and spatial exposure to drought and pest threats are attractive. Some farmers have contended that receiving income from wheat in the middle of the typical production year makes double cropping more desirable (Jordan and Harris).

This paper has two objectives. The first is to propose a model of individual decision makers who must allocate a fixed resource between two outputs which have uncertain and possibly interdependent returns. This acreage allocation decision model can be estimated without a priori knowledge of the risk attitudes of the decision maker. The second objective is to use the decision model to explain the aggregate pattern of double-cropped wheat and soybeans in the southeastern United States with emphasis on predicting future use patterns and assessing the relative importance of factors affecting double-cropped acreage.

Understanding the future course of double

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[1] For example, Debrah and Hall found for a sample of 49 Kentucky farms that the coefficient of variation on soybean yield was 54% higher but average yield was 39% lower for double-cropped compared to single-cropped soybeans.

[2] McArthur showed that pesticide expenditures were higher on double-cropped soybeans; Marra and Carlson conclude that input expenditures differences are declining in recent years. Minimum tillage, a component of more double-cropped systems, requires higher levels of management (Rahm and Huffman, Lewis and Phillips).

cropping with its changes in pesticide use, tillage practices and management requirements could be useful for research allocations and policies on soil conservation and pesticide use (Kramer, McSweeny, and Stavros). In addition, both wheat and soybean carryover stocks are linked to double cropping. Estimates from this model allow one to recover acreage response elasticities for the major factors affecting double-cropped acreage.

Standard approaches for evaluating technology adoption include fitting logistic functions to aggregate data (Griliches) or estimating dichotomous choice models (Rahm and Huffman, Burrows). These models are limited by their exclusion of yield and price variances and covariances and by their inflexible forms. Acreage adjustment models which have included uncertainty typically have been limited to single commodities without consideration of enterprise covariances (e.g., Behrman), though Just suggests how covariance might be included in a partial adjustment framework. Multiple-enterprise innovations have unique price and cost structures. Input use and yield per acre can differ between a given crop grown in two distinct ways even though the product price is the same. The riskiness of such innovations involves the covariances in output prices as well as yields. Relatively new methods are available to decompose covariance terms so that one need not ignore them or resort to restrictive assumptions on utility functions (Grant).

The Theoretical Model

In this section a decision model is developed which allows explicitly for the effect of the covariance of returns but which is a function of observable variables. The individual producer faces a decision involving two possible enterprises or outputs: full-season soybeans and double-cropped wheat and soybeans. His objective is to maximize the expected utility of profit from his chosen soybean acreage, L, by the optimal choice of the proportion, Y, of the acreage to be double-cropped.[3] The utility function, U, is defined on one-period profit, π, where uncertainty can arise from variable price and yield. The standard utility assumptions apply, except that, through the use of a covariance decomposition method known as Stein's theorem (Grant, Rubenstein) the sign and magnitude of the first and second derivatives of the utility function (and, hence, Pratt-Arrow risk attitudes) need not be specified or imposed in advance. These parameters of the utility function become estimated parameters in the model, allowing the data to reveal risk attitudes rather than having to resort to imposing ad hoc or exogenously determined measures on the model.

The individual's utility of profit is defined as

$$(1)\quad U(\pi) = U[(\alpha P_s SY + rP_w WY + P_s S(1 - Y) - C(Y, r))L],$$

where $U(\pi)$ is utility of profit from the soybean acreage; α, the ratio of double-cropped soybean yield relative to full-season soybean yield, $0 < \alpha \leq 1$; P_s, the uncertain market price of soybeans per bushel; S, the uncertain yield of full-season soybeans in bushels per acre; Y, the share of total soybean acreage double-cropped; r, 1 + the opportunity interest rate on operating capital; P_w, the uncertain market price of wheat per bushel; W, the uncertain yield of wheat in bushels per acre; $C(Y, r)$, the total cost of production per acre for the soybean acreage including both the single- and double-cropped acreage; and L is the total acreage planned to be either single or double cropped.

Equation (1) is a function of four random variables, P_s, S, P_w, and W. The specific form of Stein's Theorem used here requires the assumption that total revenues are bivariate, normally distributed random variables even though no specific assumption about the distribution of yield is implied. The producer maximizes the expected utility of profit, $EU(\pi)$, with respect to the proportion of total soybean acreage double cropped, Y. This is a utility function with one control variable similar to one which Pope examines using a primal-dual approach. The first-order condition for a maximum, FOC, can be written (with $'$ denoting derivatives) as

$$(2)\quad FOC = \delta EU(\pi)/\delta Y = E\{U'(\pi)[(\alpha P_s S + rP_w W - P_s S - C'(Y, r))L]\} = 0.$$

The change in the expected utility of profit from a one-unit change in the double-cropped proportion, Y, is the expected marginal utility of additional revenue from the double-cropped acreage minus the foregone revenue from the single-cropped acreage less the net addition to total cost from the increase in double-cropped area. C' is the marginal cost of shifting area from single to double-cropped soybeans, rather than

[3] The multiproduct diversification possibilities have many similarities to a technology adoption model by Just and Zilberman.

the traditional marginal cost as a function of output.

Taking the expectations operator, E, through (2) gives

$$(3)\quad EU'(\pi)\{[(\alpha-1)E(P_sS)+rE(P_wW) - C'(Y,r)]L\}+(\alpha-1)L \operatorname{cov}(U'(\pi),P_sS)+rL\operatorname{cov}(U'(\pi),P_wW)=0.$$

Dividing through by L and applying Stein's Theorem to $\operatorname{cov}(U'(\pi), P_sS)$ and $\operatorname{cov}(U'(\pi), P_wW)$ gives

$$(4)\quad EU'(\pi)(\alpha-1)E(P_sS)+EU'(\pi)rE(P_wW) - EU'(\pi)[C'(Y,r)]+(\alpha-1)EU''(\pi) \cdot\{(\alpha Y-Y+1)L\operatorname{var}(P_sS) + rYL\operatorname{cov}(P_sS,P_wW)\} + rEU''(\pi)\{(\alpha Y-Y+1)L\operatorname{cov}(P_sS,P_wW) + rYL\operatorname{var}(P_wW)\}=0.$$

Stein's theorem allows one to find an exact representation of the unobservable covariance of marginal utility and crop revenue in terms of observable variances and covariances of wheat and soybean revenues.[4] The Stein result is that for random variables C and D, the covariance of C and $g(D)$ is $Eg'(D)\operatorname{cov}(C, D)$ (Rubenstein). The covariance decompositions in (4) use this result and various substitutions for π and the variances of returns. An example of the algebraic steps of the decomposition is available from the authors upon request.

The Empirical Model

The relatively short time series available for this application allows only a few parameters to be estimated and, therefore, certain simplifications were necessary. Multiyear considerations, such as crop rotations to combat pests or conserve nitrogen and soil, are important on individual farms, but they will be ignored in this state-level study. Also, to comply with the only available primary data on double cropping, the share of total soybean acres double cropped (not total double-cropped acres) is the dependent variable. Total soybean acreage is affected by a broad range of factors, but these are assumed independent from the double-cropping decision. We recognize that this is a strong separability assumption for multiproduct firms; the multiproduct methods of Antle and Aitah and the approximate separability tests of Shumway may be helpful in assessing the seriousness of bias introduced by this assumption. The available double-cropping data only allow a lower mean return for the double-cropped soybeans to be included in the model. Although the yield variance of double-cropped soybeans is expected to be different, as well, no double-cropped yield data were available to make this distinction. The lower mean revenue from the double-cropped soybeans is a result of lower expected yields. Because both soybean types are harvested at the same time, output price will be the same for each. The model does imply diversification possibilities through the statistical dependence between the revenues of the three crops: wheat, full-season soybeans, and double-cropped soybeans.

Because this is a model of individual behavior applied to aggregate data, output level will surely affect output price. This effect was circumvented by treating output price as an endogenous variable by using the appropriate futures price as the expected price. Also, from Holthausen it is clear that opportunities to participate in futures markets may affect production decisions; price expectations were quantified by the use of quotations from futures contracts for soybeans and wheat following Gardner, but we ignore explicit inclusion of hedging opportunities in this application in the interest of tractability and data availability.

No explicit fixed cost of adoption is considered. The focus is on the land allocation decision. This adoption decision is unique in that it is made every year in which soybean acreage is planned. Once the first decision to double crop is made, the fixed adoption costs become sunk relative to future adoption decisions. In the empirical analysis, however, any amortized costs of additional equipment required for double cropping are captured in the measure of marginal adjustment cost of acreage, $C'(Y, r)$.

The opportunity interest rate is included implicitly as a component of total cost, $C(Y, r)$, and the revenue from the wheat crop, rP_wW. In a double-cropped system the producer must borrow operating capital earlier in the growing season to plant the wheat crop, but he also has the opportunity to use the mid-period wheat income to defray some operating costs later in the season.

Only the marginal cost of shifting area from single to double cropping needs to be measured to make the cost component of the model operational. Separate total cost functions for each of the three crops are not needed in the speci-

[4] Dwight Grant introduced us to this theorem, and we record here our indebtedness. For examples of formal proofs, see Amemiya or Rubenstein.

fication of (4). The marginal cost term is denoted as GY and it replaces $C'(Y, r)$ in (4), leaving the interest rate effect implicit in G. The term G is the marginal adjustment cost per acre. This adjustment cost is measured using state-level budget data on full season soybeans and double-cropped wheat and soybeans as described below in the data section.

Solving (4) for optimal Y (denoted as Y^*), rearranging terms, and using the relation for the expectation of the product of two random variables: $E(CD) = E(C)E(D) + \text{cov}(C, D)$, gives[5]

$$(5)\quad Y^* = [EU'(\pi)X_1 + EU''(\pi)X_2]/[EU'(\pi)X_3 + EU''(\pi)X_4],$$

where Y^* is the optimal proportion of soybean acreage double cropped, X_1 is $(1 - \alpha)EP_sS - rEP_wW$, X_2 is $(1 - \alpha)L\ \text{var}(P_sS) - Lr\ \text{cov}(P_sS, P_wW)$, X_3 is $-G$, and X_4 is $(\alpha - 1)^2L\ \text{var}(P_sS) + r^2L\ \text{var}(P_wW) + [2(\alpha - 1)]rL\ \text{cov}(P_sS, P_wW)$.

We arrive at the equation to be estimated by normalizing on $EU'(\pi)$. If constant absolute risk aversion is assumed, then the normalized ratios, $EU'(\pi)/EU'(\pi)$ and $EU''(\pi)/EU'(\pi)$, can be thought of as constants that do not depend on the elements of π. The estimating equation is

$$(6)\quad Y^* = (B_1X_1 + B_2X_2)/(B_3X_3 + B_4X_4) + \in,$$

where $B1$ and $B3 = EU'(\pi)/EU'(\pi)$ and $B2$ and $B4 = EU''(\pi)/EU'(\pi)$. The error term ($\in$) is assumed to have an expected value of zero, is uncorrelated with the X's, and takes into account additional factors known to decision makers but not observable by the authors. This parameterization of the first-order condition for expected utility maximization is similar to that used by Antle and derived in an alternate manner by Just and Zilberman.

The Data

The study area is the set of eight southeastern states in the United States for the 1968–86 period. This region has undertaken the most double cropping and has the most complete data available (Louisiana and Mississippi are omitted because of incomplete data). Data requirements for each state and year include total soybean planted acreage, expected total returns from each crop, the variances and covariance of the revenue for each enterprise, the relative yield of single- and double-cropped soybeans, the cost of operating capital, and production costs for both cropping systems for the period of the analysis. Expected total revenue, variances, and covariances of the revenues were calculated using state-level yield data from the three crop years prior to the decision year. Following Gardner, the November quotation for the appropriate futures contract is used as the expected price for each crop. The state average yields and season average crop prices are taken from USDA's *Agricultural Statistics*. Futures prices are taken from the Chicago Board of Trade's *Statistical Annual*. All prices are deflated by the index of prices paid by farmers (1977 = 100) (USDA). The standard variance and covariance formulas were applied to data from the three previous crop years, producing a time series for each of these variables. This method of calculation adheres to the guidelines suggested by Young and used by Behrman for representations of risk in time-series analysis. Modeling a rational expectation formation process for crop revenue might be preferred, but with a limited time series we chose a simple three-year, moving-average process for expected yield and assumed that farmers use futures price information in their expectation formation. The use of state-level yield and price information in the variance calculations may introduce some aggregation bias because the variance faced by individual farmers may be larger than the variance calculated at the state level.[6] County-level yield data from North Carolina were used to estimate the parameters of the model. Little difference in the county estimates relative to those using state-level data was found (Marra and Carlson). Statistically significant parameter estimates associated with the variances and covariances are more likely to be found with individual farm data.

The yield of double-cropped soybeans relative to full-season soybeans, α, is available from the 1978 and 1982 USDA cost of production surveys. A logistic time trend for α for each state

[5] Just and Zilberman analyze a similar problem of land allocation to two technologies, one traditional and one modern. They assume a significant fixed cost of adoption of the new technology and, thus, their method leads to two decisions: the adoption decision and the land allocation decision, given the adoption decision. To derive their result, the standard mean-variance utility function assumption was applied. With our theoretical derivation, we have not relied on a mean-variance utility function or a Taylor series approximation. It is possible to estimate a measure similar to a Pratt-Arrow risk aversion coefficient based on real-world decisions by applying our model to appropriate farm-level data. Taking $EU'(\pi)$ and $EU''(\pi)$ as first order approximations of $U'(\pi)$ and $U''(\pi)$, the approximate mean Pratt-Arrow measure of risk attitudes can be estimated with appropriate microlevel data (Antle).

[6] Debrah and Hall found that coefficients of variation in net income were about twice as high for individual farms as for county aggregates for all soybeans.

was calculated using these two years as reference points. Not all states' relative yields were reported in both surveys, so experimental information was used in some cases to fill in missing data. For farmers in those states reported in both surveys, α increased from 1978 to 1982, reflecting the improvement in pesticides available, soybean and wheat varieties suitable for double cropping and, probably, producers' increased management abilities as they learned more about the new cropping system (Marra and Carlson).

Data on actual production costs for the two cropping systems are sparse. A time-series, cross-section regression model was fit to twenty-three observations from state budgets to fill in missing data points over the 1968 to 1986 period. The difference in per acre production costs between double-cropped wheat-soybeans and full season soybeans was regressed on a cubic regression of time and state dummy variables ($R^2 = .8$). These estimated costs, deflated by the method described above, became the data for G in the state-level estimation of the parameters of (6).

The cost of operating capital is the average Production Credit Association interest rate for the year just preceding the crop year (USDA), which corresponds to the expected time of the acreage allocation decision. All costs and returns are appropriately compounded for comparison at harvest.

Total soybean planted acreage and the proportion of soybean acreage double cropped were taken from unpublished USDA survey data and USDA *Crop Production* bulletins. For each state, the 1972 and 1973 proportions were missing. A proxy was based on the correlation between the proportion of total soybean acreage planted in narrow rows and the proportion double cropped. The proxy was tried for these two years for Arkansas and a slight improvement in the residual sum of squares was obtained. Data were unavailable to try this procedure for the other states, however, so these two years were omitted from the final estimations.

Estimation Methods, Tests for Model Selection, and Results

This section contains the empirical results. First, the results of estimating the parameters of the full expected utility model [equation (6)] are presented for the individual states in the study. Then, the results of estimating the parameters of a model that retains the structure of the full expected utility model, but where the parameters associated with variances and covariances of returns are constrained to equal zero (the constrained expected utility model) are discussed. Next, the regression results of a standard wheat supply model are presented for comparison. Various statistical comparisons of the three models are then presented and discussed. A discussion of elasticities from the model that was judged to be the best of the three is presented last. All of the empirical results presented here are based on estimation of a separate model for each state in the study. We also tried a pooled time-series cross-section model in an attempt to improve the efficiency of the parameter estimates. We found, however, that the pattern over time of double cropping in the individual states studied is sufficiently different that a regional model did not result in improved estimates.

The parameters of equation (6), which is nonlinear in the parameters, were estimated for eight southeastern states using data from 1968 to 1984 (except for 1972 and 1973). The modified Gauss-Newton algorithm (SYSNLIN, SAS) for single-equation, nonlinear regression was employed to obtain the parameter estimates given in table 1. All of the signs on $B1$ and $B3$ in the full expected utility model are as expected. Recall that $X_1 = (1 - \alpha)EP_sS - rEP_wW$, which is the negative of the additional net returns from one additional double-cropped acre. Therefore, $B1$ is expected to be negative. Also, since $X_3 = -G$, which is the negative of the marginal acreage adjustment cost and appears in the denominator of the estimating equation, $B3$ also is expected to be negative. Eight out of sixteen parameter estimates (at least one in six out of the eight states) associated with the variances and covariance of returns ($B2$ and $B4$) are statistically significant when tested using t-tests of the individual parameters (table 1). The signs on $B2$ and $B4$ depend on the signs and relative magnitudes of the variance and covariance terms involved. Therefore, there is no theoretical basis for assigning expected signs to these two parameters.

All parameter estimates in tables 1 and 2 are relative to the value for $B3$, which was fixed by the estimation routine. This underidentification problem is expected for this equation because the parameters to be estimated are representations of (or, at least, contain) utility function parameters, which are unique only up to a positive linear transformation. A normalization rule, such as setting $B3 = 1$, for all states was judged to be too restrictive, given the differences in state-

Table 1. Full Expected Utility Model Regression Results

State	Parameter Estimate (standard error)				Corrected	Model
	$B1$	$B2$	$B3$	$B4$	SST	MSE
Alabama	−0.3415*[a]	1.72E − 10	−1.9091	5.89E − 9	0.0768	0.0103
	(0.0970)	(3.69E − 9)	(0.0000)	(3.85E − 8)		
Arkansas	−0.0914*	−2.59E − 10	−1.0000	−1.97E − 9*	0.1256	0.0154
	(0.0293)	(1.20E − 10)	(0.0000)	(7.30E − 10)		
Georgia	−0.2138*	−2.06E − 9*	−1.0000	−4.54E − 9*	0.1805	0.0301
	(0.0473)	(5.00E − 10)	(0.0000)	(1.55E − 9)		
Kentucky	−0.1791*	−1.06E − 9	−1.9213	−4.13E − 9	0.1185	0.0185
	(0.0448)	(5.50E − 10)	(0.0000)	(1.96E − 9)		
N. Carolina	−0.1106*	−8.84E − 10*	−1.0000	−2.77E − 9	0.0875	0.0136
	(0.0227)	(3.10E − 10)	(0.0000)	(1.23E − 9)		
S. Carolina	−0.3329*	−3.64E − 9*	−1.8800	−1.65E − 8*	0.1101	0.0204
	(0.0894)	(1.36E − 9)	(0.0000)	(6.63E − 9)		
Tennessee	−0.0990*	−5.54E − 10	−1.0000	−2.16E − 9*	0.1199	0.0121
	(0.0239)	(2.50E − 10)	(0.0000)	(8.60E − 10)		
Virginia	−0.3244*	−5.33E − 9*	−1.8348	−5.32E − 9	0.0725	0.0431
	(0.0820)	(2.25E − 9)	(0.0000)	(1.01E − 8)		

Note: Nonlinear regression estimates of equation (6); sample size is 12 for each regression.
[a] Parameter estimate is statistically significant using the decision criterion, $t^* > t(8, .025) = 2.3$.

level costs and the results of attempts to estimate the parameters of a pooled, regional model.

In addition to the full expected utility model given in (6), the parameters for two other specifications were estimated. First, the constrained expected utility model with the assumption that risk does not matter or that the individual responses to risk are masked in the aggregate was estimated (table 2). The results from the linear wheat acreage response model with input and expected output prices are presented in table 3. The parameters of the constrained expected utility model were all statistically significant and all had the expected signs. The wheat acreage response model generally performed well in terms of the signs of the parameter estimates, although most were not statistically significant. Although not reported to save space, the price elasticities from the acreage response model imply quite elastic responses in most cases.

Table 2. Constrained Expected Utility Model Regression Results

State	Parameter Estimate (standard error)		Corrected	Model
	$B1$	$B3$	SST	MSE
Alabama	−0.1646*[a]	−1.9140	0.0768	0.0231
	(0.0556)	(0.0000)		
Arkansas	−0.0930*	−1.0000	0.1256	0.0222
	(0.0253)	(0.0000)		
Georgia	−0.1870*	−1.0000	0.1805	0.0612
	(0.0505)	(0.0000)		
Kentucky	−0.1659*	−1.9133	0.1185	0.0243
	(0.0382)	(0.0000)		
N.C.	−0.0922*	−1.0000	0.0875	0.0243
	(0.0217)	(0.0000)		
S.C.	−0.2948*	−1.8397	0.1101	0.0323
	(0.0809)	(0.0000)		
Tenn.	−0.0846*	−1.0000	0.1199	0.0195
	(0.0213)	(0.0000)		
Virginia	−0.1462*	−1.0000	0.0725	0.0564
	(0.0289)	(0.0000)		

Note: Nonlinear regression estimates of equation (6) with parameters $B2$ and $B4$ set equal to zero; sample size is 12 for each regression.
[a] Parameter estimate is statistically significant using the decision criterion, $t^* > t(10, .025) = 2.2$.

As a first comparison of the full model and the constrained model, likelihood ratio tests were performed to test the hypothesis that the parameters involving expressions of the variance and covariance of crop returns were equal to zero in the full model ($B2 = B4 = 0$). This hypothesis was rejected for four out of the eight states ($H1$ in table 4). This provides some evidence to suggest that risk may matter in the aggregate, but it is not conclusive.

The theoretical derivation implies that, for an individual decision maker, $B1$ should equal $B3$ and $B2$ should equal $B4$. Because of aggregation to the state level, however, the parameter estimates in the expected utility models are not expected to represent exactly the first-order approximations of the first and second derivatives of U as would be the case if they were estimated from data at the microlevel. This is supported by the results of likelihood ratio tests of the hy-

Table 3. Wheat Acreage Response Model Regression Results

State	Parameter Estimate[a] (standard error) Intercept	MC	SOYFP	WHFP	Corrected SST	Model MSE
Alabama	0.3186*[b]	−0.0001	0.0566	0.0512	0.0768	0.0049
	(0.0797)	(0.0015)	(0.0322)	(0.0544)		
Arkansas	0.5410*	−0.0036	−0.0758	0.1057	0.1256	0.0062
	(0.1110)	(0.0017)	(0.0363)	(0.0614)		
Georgia	0.6997*	−0.0024	−0.0918	0.1003	0.1805	0.0088
	(0.1357)	(0.0020)	(0.0430)	(0.0728)		
Kentucky	0.4202*	−0.0027	−0.1043*	0.1656*	0.1185	0.0195
	(0.0999)	(0.0018)	(0.0400)	(0.0672)		
N. Carolina	0.4456*	−0.0021	−0.0712	0.0946	0.0875	0.0053
	(0.0874)	(0.0015)	(0.0334)	(0.0564)		
S. Carolina	0.5103*	−0.0012	−0.0838	0.0917	0.1101	0.0050
	(0.1251)	(0.0015)	(0.0323)	(0.0546)		
Tennessee	0.4749*	−0.0037*	−0.0944*	0.1409*	0.1199	0.0053
	(0.0855)	(0.0016)	(0.0336)	(0.0568)		
Virginia	0.3970*	0.0003	−0.0460	0.0740	0.0725	0.0588
	(0.0937)	(0.0018)	(0.0392)	(0.0660)		

Note: Sample size is 12 for each regression.
[a] MC = marginal cost, SOYFP = soybean futures price, WHFP = wheat futures price.
[b] Parameter estimate is statistically significant using the decision criterion, $t^* > t(8, .025) = 2.3$.

pothesis that $B1 = B3$ and $B2 = B4$ in the aggregate state level regressions ($H2$ in table 4). The aggregation function, in fact, can be quite complicated, and this model applied at the state level is an obvious abstraction of the true aggregated model. Any nonlinear micromodel applied at an aggregate level would have the same problem. Models derived from consumer utility maximization leading to demand estimation at the aggregate level are common examples of this (e.g., Huang). The trade-off is between the bias implied by assuming a relationship is linear when it is not and the bias implied by assuming the correct functional form at the microlevel and imposing bias through aggregation.

To investigate further the relative performance of the three models, we calculated the mean square prediction error from out-of-sample predictions in 1985 and 1986 for each of the models. The results are reported in table 5. On this basis of comparison the constrained expected utility model performed better than either competing model in all states but South Carolina, where the wheat acreage response model was the best. In four out of eight states the full expected utility model performed better than the wheat acreage response model.

Elasticities from the constrained expected utility model are presented in table 6. They are calculated by taking the partial derivative of Y^* [equation (5)] with $B2$ and $B4$ equal to zero and putting the partial effect in percentage terms. The partial derivatives in this case are functions of the parameter estimates and the exogenous vari-

Table 4. Likelihood Ratio Tests for $H1$ and $H2$, by State

State	SSErest $H1$[a]	SSErest $H2$	SSEunrest	Reject Hypothesis[b] $H1$	Reject Hypothesis[b] $H2$
Alabama	.25428	21.695	.09261	yes	yes
Arkansas	.24445	26.793	.13863	no	yes
Georgia	.67290	12.759	.27087	yes	yes
Kentucky	.26778	1392.920	.16615	no	yes
North Carolina	.26718	1663.850	.12280	yes	yes
South Carolina	.35569	12.091	.18405	yes	yes
Tennessee	.01946	1297.490	.01212	no	yes
Virginia	.62038	34.769	.38814	no	yes

[a] $H1$: $B2 = B4 = 0$ and $H2$: $B1 = B3$ and $B2 = B4$ in the full, expected utility model.
[b] Reject H_i if $F(2, 10) > 4.10$ for $\alpha = .05$.

Table 5. Root Mean Squared Error for Out-of-Sample Predictions: Three Models

State	Wheat Acreage Response Model	Constrained Expected Utility Model	Full Expected Utility Model
	(root mean squared error)		
Alabama	.1128	.0426*[a]	.2074
Arkansas	.1871	.0577*	.1443
Georgia	.1819	.0644*	.1218
Kentucky	.2286	.0117*	.0724
North Carolina	.1054	.0716*	.1458
South Carolina	.0682*	.1977	.0981
Tennessee	.2135	.0482*	.0979
Virginia	.1223	.0775*	.1770

Note: Predictions for 1985 and 1986 using models estimated for 1968–84.
[a] Lowest value for each state.

ables. All of the elasticities have the expected signs. The elasticity with respect to expected wheat revenue generally is four to five times larger in absolute magnitude than the elasticity with respect to expected soybean revenue. This is reasonable because, as expected soybean revenue increases, full-season soybeans become more valuable, but so do double-cropped soybeans. On balance the effect should favor full-season soybeans but to a smaller extent than would a similar change in expected wheat revenue. The elasticity with respect to changes in the cost of increasing double-cropped acreage is similar on average (in absolute value) to the effect of changes in expected wheat return. At first glance, the elasticities appear small in absolute magnitude. However, soybean acreage in the Southeast amounts to 12 to 14 million acres in most years, so a slight change in the proportion double-cropped can mean a significant change in wheat acreage.

Table 6. Elasticities from the Contrained Expected Utility Model Evaluated at the Sample Means

State	Elasticity of the Proportion of Total Soybean Acreage Double-Cropped with Respect to: Expected Soybean Revenue	Expected Wheat Revenue	Marginal Cost
Alabama	−0.00024	0.00082	−0.00063
Arkansas	−0.00019	0.00083	−0.00060
Georgia	−0.00031	0.00171	−0.00110
Kentucky	−0.00016	0.00103	−0.00102
North Carolina	−0.00019	0.00114	−0.00125
South Carolina	−0.00031	0.00161	−0.00113
Tennessee	−0.00018	0.00087	−0.00066
Virginia	−0.00025	0.00126	−0.00099

Note: Computed from parameter values in table 2 using the definitions of equation (5).

Conclusions and Limitations

Because the time series used for estimation is relatively short and nonlinear hypothesis tests are only asymptotically valid, none of the statistical tests reported above are exact. The conclusions, therefore, must be based on a preponderance of the evidence presented.

There is some evidence (t-tests in table 1, F-tests of $H1$ in table 4, and relative, out-of-sample predictive ability in table 5) to suggest that the full expected utility model has value in aggregate estimation. The evidence is more convincing, though, that a model derived from the expected utility hypothesis (the constrained expected utility model) can contribute more to the understanding of acreage allocation decisions of this type than an acreage response model similar to those generally found in the literature (table 5).

The decision model developed here remains to be tested with data at the microlevel. The aggregate results suggest that the expected utility model has some merit when compared to the standard acreage supply models in understanding acreage allocation between two cropping systems.

The main limitations of the proposed method are that greater demands are placed on assembling price and quantity data, and that a nonlinear estimation procedure is required. The model has been estimated without exploiting possible primal-dual restrictions on the utility function, which Pope has suggested for similar objective functions. Future developments may show that Stein's covariance decomposition theorem also extends to other, nonsymmetrical probability distributions. Generalization of the model to more than two commodities with more complete cost specification seems possible; this probably would help to explain adoption of various technologies. Also, more applications of the model are needed with alternate revenue expectation formation processes. Finally, this decision model should be applied to a farm-level data set to

evaluate its usefulness for estimating risk attitudes from observed production decisions. We agree with Antle when he calls for a comparison of the usefulness of all of the proposed methods for evaluating risk attitudes and their effects on production decisions.

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Orderly Marketing for Lemons: Who Benefits?

Hoy F. Carman and Daniel H. Pick

The orderly marketing goal of federal marketing orders may deal with price stability or uniform flow of product to market, a choice which can have important economic implications. This study examines the impact of four fresh lemon marketing strategies on returns at the producer, FOB, and retail levels, together with marketing margins and consumer surplus. Producers, as a group, and consumers should favor a constant price strategy. Some individual producers and middlemen, however, enjoyed higher returns with constant weekly sales. Explanations of the shift in lemon sales patterns which occurred during the 1970s is examined in light of these results.

Key words: lemon marketing, marketing orders, orderly marketing.

The California–Arizona lemon industry can, on a weekly basis, recommend to the secretary of agriculture that the quantity of lemons shipped to the domestic fresh market be limited under provisions of its federal marketing order program. Designed to benefit lemon producers by increasing average prices to a level of parity prices, the weekly prorate feature of the lemon marketing order is justified as contributing to "orderly marketing." The concept of orderly marketing, while central to marketing policy embodied in the Agriculture Marketing Agreement Act of 1937 (AMAA), as amended, is not defined in the basic statutory framework for agriculture marketing orders. The declaration of policy in the AMAA, however, does associate orderly marketing with an even flow of product to market at stable prices. This is consistent with a General Accounting Office (U.S. Comptroller General) statement that "an orderly market would (1) reduce fluctuations in farm and retail prices, and (2) assure consumers a steady supply of quality products that meet consumer needs" (p. 2).

There is a seasonal pattern of demand for fresh lemons with demand being highest during the summer months of June and July and lowest during the winter months. Because of seasonal demand, stable weekly sales tend to lead to variable prices and variable weekly sales can lead to stable prices. An examination of the weekly pattern of lemon sales and prices over the 1961 through 1987 period reveals a dramatic change in marketing policy followed by the Lemon Administrative Committee (LAC) for the periods before and after 1973. Weekly lemon shipments were quite variable and prices were relatively stable from 1961 through 1972, while shipments became much more stable and prices much more variable 1974–87. While the changing pattern of shipments and prices appears rather discrete, annual LAC reports do not mention any change in marketing policy. Either weekly sales pattern can be justified as contributing to orderly marketing, but the economic results from a policy that attempts to stabilize sales can be quite different from a policy that attempts to stabilize prices.

The purpose of this article is to examine possible reasons for a change in fresh lemon shipment patterns from one which demonstrated considerable seasonal variability to one which became much more stable. We assume that shipment pattern changes benefitted one or more groups that influenced Lemon Administrative Committee decisions. While one would expect that lemon producers were the primary beneficiaries, it is not clear that they were. Returns to

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producers, marketing margins, retail level expenditures, and consumer surplus for alternative weekly shipment patterns will be estimated. Possible gainers and losers from a changing pattern of fresh lemon sales, based on total 1986–87 shipments, will be examined. This information will be used to evaluate four hypotheses for the changes observed. They are:

Hypothesis I: The LAC was responding to pressures from administrative agencies to increase fresh market shipments. Recall that supply control provisions of marketing orders were targeted as contributing to price inflation in the early 1970s.

Hypothesis II: The LAC was attempting to improve producer returns.

Hypothesis III: The LAC was responding to pressure from marketing middlemen.

Hypothesis IV: The significant growth of the export market for lemons, beginning in 1971–72, led to a changed seasonal marketing pattern.

Lemon Marketing

The California–Arizona lemon industry has had a federal marketing order program since 1941. Under this program, the Lemon Administration Committee recommends a weekly allotment of lemons for shipment to the domestic fresh market, the recommendation is routinely approved by the secretary of agriculture, and this allotment is then "prorated" among handlers based on the quantity of lemons picked by their growers during a specified period of weeks. The weekly prorate feature of the marketing order was used each marketing year from 1961–62 through 1987–88, except for 1985–86. Establishing maximum weekly fresh market shipments provides a means of price discrimination for the lemon industry because any lemons in excess of the prorate quantity can only be processed or exported. Quantitative analysis indicates that price elasticity of demand is more inelastic for fresh market sales than for fresh exports or processing sales (Kinney et al.), and annual data on allocation by markets combined with average price data indicate that weekly prorate has helped the lemon industry to maintain a significant price difference between fruit going to fresh and processing uses. Average annual on-tree prices for lemons utilized for processing were negative for twelve of the fifteen years from 1972–73 through 1986–87, while on-tree prices for lemons sold for fresh use ranged from a low of \$2.11 per carton in 1976–77 to a high of \$7.72 per carton in 1985–86 (USDA *Fruit Situation*.)[1] Crop utilization varies annually but during the five-year period 1982–83 through 1986–87, an average of 51% of the lemon crop was processed while 31% went to domestic fresh markets and 18% was exported for fresh use (Lemon Administrative Committee).

The California–Arizona lemon industry has seasonal patterns of production, harvest, and marketing. District 1 (Central California), with 14% of total acreage, usually begins harvest in October or early November, reaches a peak in January and February, and typically ends in April or May. District 2 (Southern California), which currently accounts for approximately 49% of lemon acreage, harvests and sells lemons throughout the year, but most of its fruit is picked from January through July. District 3 (California desert and Arizona), which has about 37% of total acreage, has a harvest period that begins in late July or early August, usually peaks in November and extends into February or March. Significant quantities of lemons are stored by all districts throughout the year, but especially by District 2 during the April through July period.

The relative importance of production districts has changed over time. In 1963, District 1 had only 3% of total lemon acreage, while District 2 had 85% and District 3 had 12%. Because of large new plantings, District 1's share of acreage increased to 12% and District 3's share increased to 36% in 1973, while District 2's share decreased to 52%. A review of annual reports of the Lemon Administrative Committee shows that the membership of the committee also changed in line with acreage and production. There were no grower or handler members from District 1 and 3 prior to 1 July 1971. The marketing order was amended and the secretary of agriculture appointed a new committee with members from Districts 1 and 3 to serve for the period 1 July 1971 through 31 July 1972. The term of office for committee members, appointed by the secretary of agriculture to represent various industry interests, is two years.

Shipment and Price Variability

An examination of the variability in lemon sales and prices by marketing year illustrates the changes taking place. As shown in figure 1, the

[1] Returns for lemons used for processing are positive at the packing house; but costs of handling, transportation, and picking sometimes exceed these returns, resulting in a negative on-tree price.

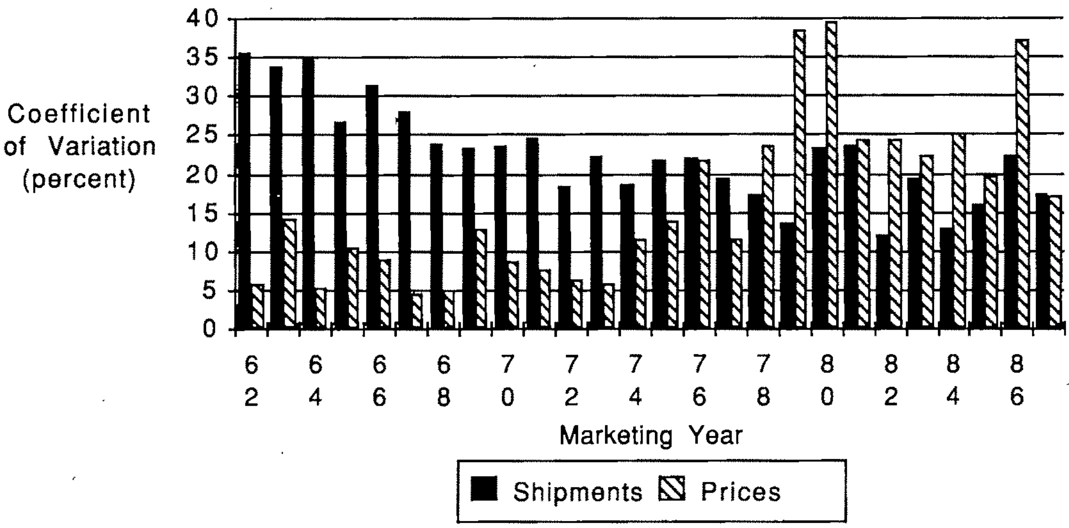

Figure 1. Coefficients of variation for annual shipments and prices of fresh market lemons, 1961–62 through 1986–87 marketing years

variability of annual lemon shipments (as measured by the coefficient of variation) decreased over time while the variability of annual prices increased. Increased variability of prices is particularly evident after the 1973–74 marketing year. An examination of the seasonal pattern of fresh lemon shipments indicates that the proportion of each year's crop sold in the second and third quarters of each marketing year (Nov.–April) tended to increase slightly over time while the proportion sold in the first and fourth quarters decreased.

An Analytical Framework for Lemon Pricing

Examination of the impact of alternative patterns of weekly sales on revenues requires estimation of the weekly demand for fresh lemons. Several empirical studies provided estimates of demand relationships for lemons (Hoos and Seltzer, Hoos and Kuznets, Nicolatus, Carman and Pick). This research builds on demand relationships in the Carman and Pick study of the impact of not using weekly prorate during the 1985–86 marketing season.

Carman and Pick estimated a linear inverse demand function for fresh lemons with weekly real FOB price specified as a function of weekly per capita fresh sales, real consumer income, lagged weekly prices, seasonal demand shifts, and a dummy variable to measure possible shifts in structure due to suspension of prorate. The use of a partial adjustment analytical framework was based on the observation that FOB prices are sticky and adjust to new equilibrium values over time rather than instantaneously. A portion of this stickiness may result from the stable nature of weekly shipments during the observation period. Processed substitutes were not included in the model, a weakness attributable to the lack of suitable data series for lemon juice and frozen lemon concentrate. There is a series on the quantity of lemons processed each year, but prices and quantities by product category and year-end inventory data required to calculate consumption are not recorded. A final limitation is that data needed for a grade variable were not available even though prices vary by grade. The proportion of fresh sales in each grade is reported, but FOB prices by grade and size are not.

This study expands on the demand relationship described above by extending the data series and by expanding the bimonthly seasonal demand shifters to weekly shifters. Several approaches are available for determining the nature of the seasonal demand shifter. These approaches include (*a*) treat all observations as a single data set and distinguish subperiods through the use of dummy variables, (*b*) distinguish subperiods (e.g., weeks or summer-winter) and treat data for each subperiod as a separate set of observations, (*c*) use a random coefficients model,

or (*d*) use a sine or cosine function.

Under perfectly competitive conditions, primary demand is at the retail level with demand at lower levels in the marketing system derived from retail demand. Thus, prices are established at the retail level by supply and consumer demand and prices at the wholesale; FOB and farm levels are derived by subtracting the relevant marketing margins. If equilibrium conditions are assumed, marketing margin relationships can be used to derive demand at one level in the system from demand at another level. Empirical studies of the food industry (Heien, Ward) provide strong evidence of markup-type pricing with prices registered at the wholesale or FOB level and then transmitted to the retail level by middlemen and store managers. The markup pricing model appears to fit the fresh lemon industry with major price changes first registered at the FOB packinghouse level in the distribution system. Working backward from the FOB level to the farm, a constant annual charge for packing, transportation, and picking is subtracted from the FOB price to arrive at a farm-level on-tree price.

Price and quantity data necessary to estimate weekly demand functions for fresh lemons are available only at the FOB level. Analysis of the impact of different marketing policies on retail expenditures, therefore, must be based on FOB prices and estimated marketing margin relationships. A common approach has been to assume that the marketing margin is constant, even though there is substantial evidence of variability in margins. Alternative margin specifications include a percentage margin, where the margin is a constant percentage of the retail or FOB price, and a combination margin consisting of both constant dollar amounts per unit of product (as for packing or transportation) and a percentage component.

Recent research for fruits and vegetables has found evidence of marketing margins which are asymmetric to price changes (Ward). Discussions with industry participants revealed a widespread perception that retail prices are sticky and that they typically respond more rapidly to FOB price increases than to price decreases. This type of pricing can be modeled with the price linkage equation:

$$(1) \quad PR_t = b_0 PFU_t + b_1 PFD_t + b_2 T + e_t,$$

where PR_t is the change in retail price (P_t) in period t from the base period (P_0), PFU_t is the sum of increases in the FOB price (PF_t) up to period t and PFD_t is the sum of decreases in the FOB price up to period t. For estimation, equation (1) is

$$PR_t = P_t - P_0$$

$$PFU_t = \sum_{t=1}^{n} \Delta PF_t, \quad \text{if } PF_t > PF_{t-1}, \quad \text{and zero otherwise}$$

$$PFD_t = \sum_{t=1}^{n} \Delta PF_t, \quad \text{if } PF_t < PF_{t-1}, \quad \text{and zero otherwise}$$

$$T = \text{a time trend variable;}$$

where $\Delta PF_t = (PF_t - PF_{t-1})$ is the change in FOB price from period $t - 1$ to period t.

If FOB and retail prices move up and down together, then b_0 and b_1 will be positive. If the retail price response to changes in FOB price is symmetric for both price increases and decreases, then one would expect to find $b_0 = b_1$. The relationship between FOB and retail prices can be expected to change if costs of performing the marketing functions change and these costs have been increasing over time. A trend variable (T) is included to detect any systematic changes in marketing costs over the period of analysis. The alternative of a weekly index of marketing costs is preferred, but development of such an index for specific markets is difficult and would add little, given the aggregate nature of available data.

Calculation of estimated consumer surplus under alternative marketing patterns provides a measure of their impact on consumers. To simplify the calculation, we assume a linear demand curve with a constant slope and an intercept that changes by week, and a weekly supply curve that is perfectly inelastic. Weekly consumer surplus is summed over the fifty-two-week marketing season to derive estimated annual consumer surplus under the marketing alternatives. Calculations are based on the equation:

$$(2) \qquad CS = \sum_{t=1}^{52} \frac{1}{2} (a_t - PR_t) Q_t,$$

where CS is the annual estimate of consumer surplus, t is the week of the marketing year, a_t is the estimated weekly intercept in the price dependent retail demand curve, PR_t is the estimated weekly retail price, and Q_t is the weekly quantity of fresh lemon sales.

Estimated Demand and Margin Relationships

Estimation of the demand relationships necessary to evaluate alternative hypotheses related to the change in fresh lemon marketing patterns requires a number of decisions on the model utilized. The first problem was to choose the best method to estimate seasonality of demand. Earlier work indicated that seasonal demand shifts for fresh lemons involved shifts in the intercept rather than changes in the slope of the demand curve (Pick and Carman). This narrowed the choice; the final decision to utilize weekly dummy variables to estimate the shifts in demand over the marketing year was based on the straightforward nature of the estimating equation and the ease of using estimated results in evaluating the hypotheses.

A second decision involved the variables to include in the inverse demand equation. The equation specification from the earlier weekly demand study (Carman and Pick) was followed (average price = function of quantity of fresh shipments, income, lagged average price, a zero–one shifter for the 1985–86 marketing year, and seasonal shift variables). Use of the partial adjustment model was based on an observed stickiness of FOB prices. The zero–one variable for the 1985–86 marketing year was included to capture the possible structural impact of not using the weekly prorate feature of the marketing order. Earlier work indicated that 1985–86 prices were below the level expected for the weekly quantities marketed. A second zero–one variable was added to isolate the impact of revised price reporting procedures followed by the Lemon Administrative Committee beginning with the 1986–87 marketing year.

The weekly price equation, as specified above, was estimated by ordinary least squares (OLS) using data for the period 1974–75 through 1986–87. The Yule-Walker method was used to correct for autocorrelation after the Durbin h-statistic led to rejection of the hypothesis of zero autocorrelation at the 5% level. The estimated weekly demand equation for fresh lemons utilized for this study is as follows:

$$
\begin{aligned}
(3)\ PF_t = {} & \underset{(-4.56)}{-1.4490} - \underset{(-1.87)}{0.1755}\ Q_t + \underset{(8.72)}{0.6013}\ Y_t \\
& + \underset{(55.43)}{.9152}\ P_{t-1} - \underset{(-4.42)}{0.2812}\ D86 \\
& - \underset{(-4.94)}{0.3630}\ D87 + DWK_t
\end{aligned}
$$

$$R^2 = .95,$$

where the variables are defined as PF_t is average weekly FOB price of lemons for domestic fresh use, dollars per carton for all grades and sizes, deflated by the monthly consumer price index (1967 = 1.00); Q_t, weekly domestic fresh lemon shipments adjusted for population, carloads per million persons; Y_t, per capita real personal income (monthly total personal income, in billion dollars) deflated by the consumer price index and divided by population, in million persons; $D86$, dummy variable for the 1986 crop year to measure the possible impact of changed buyer and seller behavior in the absence of weekly prorate (1 for 1985–86, 0 otherwise); $D87$, dummy variable for the 1987 crop year to measure the possible impact of revised price reporting and recording procedures by the LAC (1 for 1986–87, 0 otherwise); DWK_t are weekly dummy variables, which have a value of one for week t and zero otherwise, included to measure weekly shifts in the demand for fresh lemons [week one is the first week of August (the first week of the marketing year which runs from August through July); the base week (week 52) is the last week of July, which is the last week of the marketing year], the estimated weekly dummy coefficients are presented in table 1; and t-statistics are in parentheses.

Each of the estimated coefficients for weekly shipments, income and lagged price has the expected sign and all are statistically significant at the 5% level with most being significant at the 1% level (one-tailed test). The two dummy variables, $D86$ and $D87$, included to capture the structural effects of operating without prorate during the 1985–86 marketing year and revised price reporting procedures during the 1986–87 marketing year, each have a significant negative coefficient. Average weekly shipments increased during 1985–86 when prorate was not utilized and increased shipments are associated with decreased prices.[2] However, the negative coefficient on $D86$ indicates that weekly prices decreased in the absence of prorate, even after allowing for increased shipments. The reduced price during 1986 could be explained by factors such as pricing behavior and the exercise of market power by large buyers or by a change in market conditions not accounted for by the model.

The pattern of weekly demand during the estimation period, as given by the coefficients reported in table 1, is plotted in figure 2. It is a

[2] The variable for sales and $D86$ are not independent. Previous work indicates that sales increased an average of approximately 13 carloads per week during the period when prorate was not used (Carman and Pick).

Table 1. Estimated Coefficients for the Weekly Dummy Variables DWK_1 through DWK_{51} in Equation (3), 1974–75 through 1986–87 Marketing Years

Week	Coefficient	Week	Coefficient	Week	Coefficient
1	−0.2829**[a]	18	−0.4925*	35	−0.3706*
2	−0.3373*	19	−0.6153*	36	−0.4072*
3	−0.4546*	20	−0.4895*	37	−0.3918*
4	−0.4454*	21	−0.4490*	38	−0.4019*
5	−0.3881*	22	−0.4358*	39	−0.3233*
6	−0.3716*	23	−0.5380*	40	−0.3414*
7	−0.2887**	24	−0.5383*	41	−0.3343*
8	−0.4908*	25	−0.5333*	42	−0.2608**
9	−0.2217**	26	−0.5058*	43	−0.2463**
10	−0.4865*	27	−0.5504*	44	−0.2902**
11	−0.3879*	28	−0.4868*	45	−0.2408**
12	−0.5379*	29	−0.4520*	46	−0.1963
13	−0.6453*	30	−0.4599*	47	−0.2158*
14	−0.6114*	31	−0.4510*	48	−0.1691
15	−0.5022*	32	−0.3929*	49	−0.1857
16	−0.4235*	33	−0.3995*	50	−0.0800
17	−0.5238*	34	−0.4158*	51	−0.0400

Note: All measures of significance based on a two-tailed test.
[a] Single asterisk indicates significantly less than week 52 at the 1% level; double asterisk indicates significantly less than week 52 at the 5% level.

coincidence that the last week of the marketing year (the last week of July), which was used as the base week, was the week with highest demand. Thus, each of the estimated coefficients has a negative sign. Note that the average of the fifty-two weekly demand shifters is −.38; the price in the last week of July (the base week) is \$.38 per carton above the average for the year, other factors equal. The estimated price equation for each week during the marketing year can be derived by substituting the relevant coefficient from table 1 for DWK_t in equation (3).

Asymmetric Marketing Margins

A choice of the functional form for the marketing margin from among the several alternatives was based on examining the four hypotheses. The form of the FOB-to-retail margin for fresh

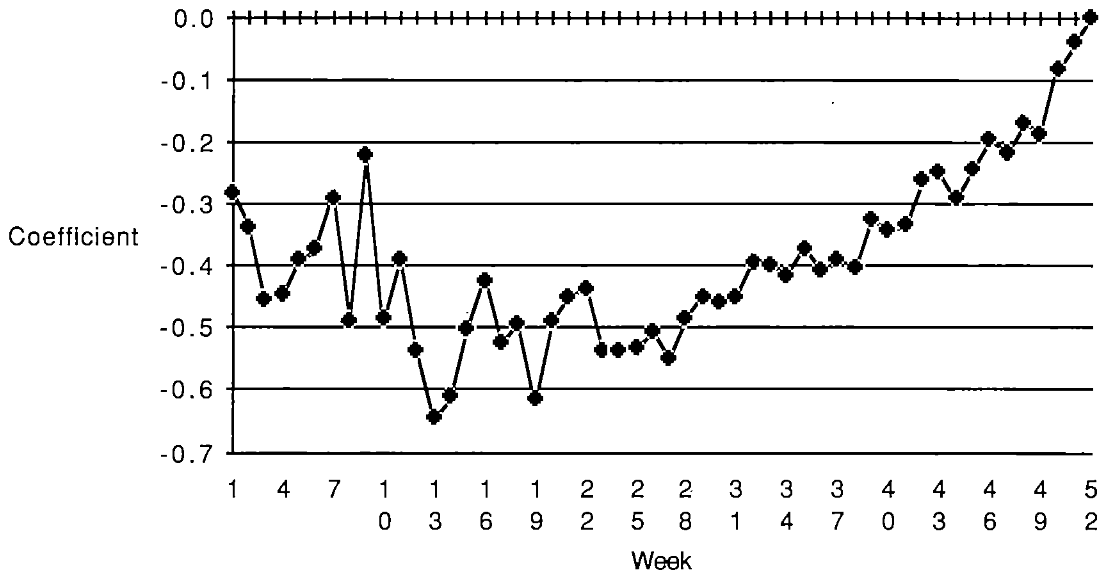

Figure 2. Estimated coefficients for the weekly demand shifter as reported in table 1

lemons has not been firmly established, but recent research on a limited data set supports the existence of asymmetric margins in some important markets. The impacts of a constant margin, a percentage margin, or a margin with both constant and percentage components are quite predictable and are of limited use in examining the hypothesis (III) that the LAC was responding to pressure from marketing middlemen. A constant dollar margin provides the same total revenue to middlemen regardless of the sales pattern; a percentage margin or a margin with percentage components will be maximized with a sales pattern which maximizes average FOB price. Thus, producer and middlemen interests coincide with the latter two margin types. With an asymmetric margin, however, price variability may have quite different impacts on producers and middlemen. For this reason, an asymmetric margin relationship was chosen.

Asymmetric marketing margin relationships for fresh lemons in four retail markets have been investigated (Karrenbrock, Pick, and Carman). Estimated coefficients indicated that retail prices responded more to FOB price increases than to decreases in each of the markets. The FOB-retail price relationship for the Denver market will be used to illustrate the implications of different orderly marketing policies on FOB-level returns and consumer expenditures for a given total quantity of fresh lemon sales. Because of a lack of aggregate marketing cost data for all fresh lemon sales, it is difficult to determine the degree to which the Denver margin relationship represents the total United States. The Denver margin equation was initially estimated using OLS, but the Durbin-Watson statistic adjusted for no intercept indicated the presence of autocorrelation. The generalized least squares method, in which the OLS residuals are used to estimate the covariance matrix, was then used to correct for autocorrelation. The margin relationship estimated for the Denver retail market, based on retail price data for forty-six weeks beginning 3 February 1985, was

$$\text{(4)} \quad PR_t = \underset{(5.96)}{1.49PFU_t} + \underset{(4.78)}{0.86PFD_t} - \underset{(-0.55)}{0.06T} \qquad R^2 = .88,$$

where the values in parentheses are t-statistics. The F-statistic for the test that $b_0 = b_1$ was significant at the 5% level, indicating that retail lemon prices in the Denver market responded more to FOB price increases than they did to FOB price decreases during the observation period. Calculated elasticities of price transmission (mean values) based on equation (4) were 0.55 for FOB price increases and 0.32 for FOB price decreases. The estimated coefficient on T, included to measure any systematic changes in marketing costs, was negative but not significantly different than zero. Thus, one can conclude that there was no evidence of a change (either increase or decrease) in marketing costs for the Denver market during the period of analysis.

The major components in the margin between the packinghouse and farm prices are picking, transportation, and packing. Average picking and transportation charges are similar from district to district, but packing charges vary because of storage practices and capacity utilization. Average margins used for this study by lemon production district are as follows: District 1 (Northern California), \$3.70 per carton; District 2 (Southern California), \$4.57 per carton; and District 3 (California Desert and Arizona), \$3.64 per carton. These margins were from sample averages of actual margins for the 1986–87 marketing year. The weekly margin was calculated as a weighted average of district shipments. Seasonal variation in the relative importance of each district results in a weekly change in average industry margins.

A Comparison of Marketing Alternatives

Estimated weekly price and margin relationships presented above are used to evaluate the impact of different sales patterns on total revenue at the FOB and on-tree levels and on annual consumer expenditures for 1986–87 fresh lemon sales. Domestic fresh market lemon sales totalled 15,732 carloads during the 1986–87 marketing year.[3] Four weekly sales patterns for total sales of 15,732 carloads will be evaluated: (*a*) actual weekly sales for the 1986–87 marketing year, (*b*) constant sales of 302.5 carloads per week for each week during the marketing year, (*c*) weekly sales varying to maintain a constant real FOB price of \$3.42 per carton (nominal price of \$11.44 per carton with total sales of 15,732 carloads), and (*d*) weekly sales which approximate the pattern to maximize total revenue at the FOB level (again totalling 15,732 carloads). Derivation of an approximate revenue-maximizing sales pattern with a total quantity constraint

[3] A carload is 1,000 cartons with a net weight of 38 pounds per carton.

proceeded in two steps. First, weekly sales necessary to yield a long-run price flexibility of demand equal to one were calculated (yielding a total of just over 18,000 carloads). Then these weekly quantities were reduced proportionately to the constraint of 15,732 carloads to maintain equal marginal revenues for each week during the marketing year.

Sales by four-week periods as a percentage of total 1986–87 sales for three of the alternatives (actual sales, constant price, and approximate revenue maximization) are shown in figure 3. Sales for constant 302.5 carloads per week would total approximately 7.7% for each four-week period. The constant price alternative has very low sales during the November through January period and very high sales June–July, compared with other weekly quantity allocations. It is unlikely that producers in Districts one and three would support such low sales during their peak production period and sufficient quantities of high grade lemons might not be available during some years to satisfy the June–July sales allocation. Other allocations would require relatively little change from recent actual sales and are feasible.

Calculation of total revenues at the FOB, retail, and farm levels for each of the alternative sales patterns proceeded in a series of steps. First, the estimated FOB price equation was used to calculate real FOB prices for each sales pattern (including actual sales) and these real prices wer then converted to nominal 1986–87 prices. Th estimated FOB to retail marketing margin wa added to the nominal FOB price to obtain estimated weekly retail prices. Then, estimate 1986–87 weighted average weekly packing transportation, and picking charges were subtracted from FOB prices to obtain weekly farm-level prices. Finally, the estimated weekly price at the farm, FOB, and retail levels were multiplied by weekly sales for each of the four alternative sales patterns to obtain total revenue and these were summed over the 52 weeks o the 1986–87 marketing year. These calculate total revenues are presented in table 2.

Examination of estimated total revenues at th farm, FOB, and retail levels in the fresh lemo marketing system reveals some interesting relationships (table 2). First, the particular orderl marketing strategy followed can have an important impact on producer returns, whethe measured at the FOB or on-tree level. A strategy of constant sales in the face of seasona variation in demand for fresh lemons resulted i much lower total revenue at the farm and FO levels than did a strategy of varying the weekl quantity to maintain a stable price. As shown i table 2, the constant price strategy increased total returns at the farm and FOB levels by $20.9 million (23%) and $23.0 million (15%), respec-

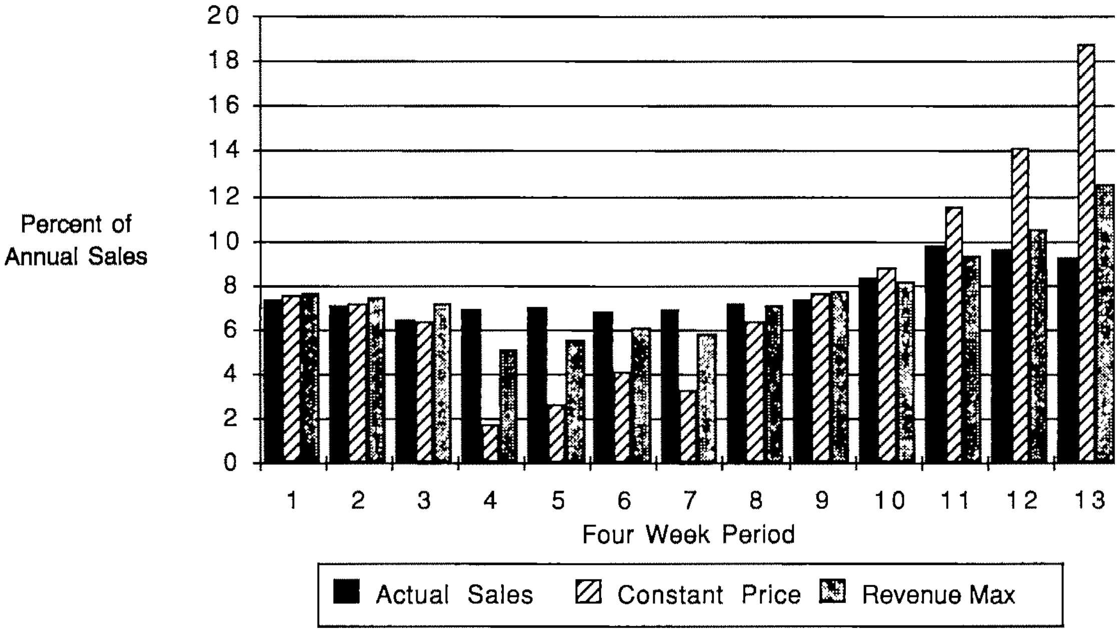

Figure 3. Four-week period percentages of annual sales by sales pattern, 1986–87 marketing year

Table 2. Estimated Total Revenues at Farm, FOB, and Retail Levels for 1986–87 Fresh Lemon Sales with Associated Margins: Four Alternative Weekly Sales Patterns

Marketing Strategy	Estimated Total Revenue at Different Levels in System				
	Farm	Margin	FOB	Margin	Retail
	($ mill.)				
Actual sales	94.6	66.1	160.7	422.4	583.1
Constant sales	92.2	65.7	157.9	425.9	583.8
Constant price	113.9	67.0	180.9	395.7	576.6
Revenue max	128.8	66.6	195.4	409.4	604.8

tively, over the constant weekly sales strategy. An FOB revenue-maximizing sales pattern further increased revenues by $15.7 million and $14.5 million at the farm and FOB levels, respectively, over the constant price strategy. Actual industry weekly sales resulted in farm-level and FOB total revenues only slightly greater than the constant sales strategy, and total revenues were significantly less than from a constant price strategy.

The FOB-to-retail margins vary in response to the marketing strategy followed. The constant sales strategy, which results in variable prices, yields the highest FOB-to-retail margin totalling $425.9 million, while the constant price strategy results in a margin of $395.7 million (calculated from table 2). The margin for the actual sales pattern of $422.4 million is very close to that resulting from a constant sales strategy, while the revenue-maximizing strategy provides a margin of $409.4, which is midway between the high and low margins. With an asymmetric margin, middlemen clearly benefit from movement away from varying weekly sales with constant prices and toward constant weekly sales with variable prices. If the FOB-to-retail margin was a percentage or had a percentage component, then middlemen would prefer the sales pattern yielding the highest average FOB price (the revenue-maximizing pattern).

The economic results of various marketing strategies may vary by production district because of different seasonal production patterns. The weekly percentages of actual weekly sales for each district were applied to the total weekly sales for each sales pattern to investigate the impact of each sales strategy on total revenue at the producer level. Comparison of the constant price and constant weekly sales strategies in table 3 indicates that Districts 1 and 2 producers would have enjoyed the largest returns with a constant price strategy but District 3 producers would have preferred the constant quantity strategy. In fact, District 3 estimated total revenue from the constant quantity strategy was greater than from the sales strategy which would have approximately maximized total industry sales revenue from sales of 15,732 carloads during the 1986–87 marketing year.

Consumer surplus was calculated for a linear retail demand curve based on the estimated FOB demand plus the estimated marketing margin. Estimated annual consumer surplus for 1986–87 fresh lemon sales totaled $93.6 million for the constant weekly sales alternative (302.5 carloads per week). This was increased by 24% to $115.8 million by the marketing strategy based on maintaining a constant weekly FOB price of $11.44 per carton by varying sales in line with seasonal demand. Consumer surplus was decreased by 8% to $86.4 million by a sales pattern designed to maximize total FOB-level revenues. The actual pattern of weekly sales resulted in estimated consumer surplus of $97.9 million. It is interesting, but not surprising, that the stable price marketing alternative resulted in higher consumer surplus than did constant weekly shipments, even though total retail revenue (table 2) was higher with constant prices. Massell demonstrated a similar result with his integration of

Table 3. Estimated Total Farm-Level Revenue by Production District for 1986–87 Fresh Lemon Sales: Four Alternative Weekly Sales Patterns

Marketing Strategy	Estimated Total Farm Revenue by Production District		
	District 1	District 2	District 3
	($ mill.)		
Actual sales	10.883	61.453	22.226
Constant sales	10.667	57.134	24.435
Constant price	12.339	80.627	20.907
Revenue max	13.210	92.699	22.874

the Waugh-Oi results on the effects of price stabilization on consumer and producer surplus.

Who Benefits?

Market allocations for California–Arizona fresh lemons changed rather abruptly from one that resulted in relatively stable prices over the marketing year to one that resulted in variable prices. Because the lemon industry regulates weekly fresh lemon shipments under a marketing order designed to improve producer returns, one would expect the change in marketing policy to benefit producers as a group. Our estimates indicate, however, that this was not the case. Total industry returns at the producer level are clearly much less for a marketing strategy that emphasizes stability of shipments as opposed to price stability. Following is a discussion of the hypothesized reasons for the change in lemon marketing patterns.

Hypothesis I

Concerns about the effects of marketing orders on inflation and on consumers received considerable publicity during the 1970s. Federal Trade Commission and Justice Department officials charged that marketing orders raised the prices of regulated commodities, and that consumers were ignored in the establishment of marketing order policies. The hypothesis that the LAC was responding to public pressure or to pressure from the secretary of agriculture, who is charged with protecting the interests of consumers and the public (as well as producers), is not supported by our estimates. Consumers are made worse off by stable sales in the face of seasonal demand. They pay more for a given quantity of lemons and also have a significant reduction in consumer surplus. If the LAC was responding to pressure from administrative agencies, the response would have more likely been evidenced by increased total fresh market shipments rather than a change in seasonal shipments. Total fresh lemon shipments, however, remained quite stable during the 1970s.

Hypothesis II

Support for the hypothesis that the LAC was attempting to improve producer returns is mixed. Estimates in this study clearly indicate that industry-wide total returns to producers are reduced when moving from relatively stable prices to relatively stable shipments for a given total quantity of fresh lemons. It is likely, however, that individual producers improved their returns because of the seasonal nature of production. District 3 producers appear to have improved the percentage of their crop going to the domestic fresh market (and their average returns) relative to the other two districts. As shown in table 3, District 3 producers realized the largest estimated total revenue from the marketing strategy of constant weekly sales, and the actual 1986–87 weekly sales pattern yielded only slightly lower total revenue than did the industry revenue-maximizing sales pattern for a crop of 15,732 carloads. Estimates in table 3 indicate that Districts 1 and 2 producers would have been much better off with a constant price strategy than with the actual sales pattern during the 1986–87 marketing year. Districts 1 and 2 gains when moving from the actual sales pattern to a strategy of maintaining constant prices ($20.5 million) were several times the loss for District 3 (−$1.3 million). District 3 typically had three out of the eight grower members on the LAC after the 1971 marketing year. Thus, they would have needed support from other members of the LAC to change the sales pattern. Such support may have been relatively easy to secure during the weeks when District 3 accounted for the majority of lemon supplies.

Changing production patterns, which led to the change in LAC membership, may have influenced weekly prorate allocations. District 2 supplies most of the lemons marketed during May, June, and July, and its share of industry production decreased significantly from the earlier to the later period. This changing availability of seasonal supplies may have been reflected in fresh market allocations. Such a change is difficult to verify because the weekly prorate was used during most weeks during most marketing years, and, presumably, limited the quantity of lemons sold on the fresh market when used.

Hypothesis III

Given the assumption of asymmetric marketing margins, middlemen clearly gained from movement toward a marketing pattern that resulted in more variable prices. This lends support to the hypothesis that the LAC may have responded to pressure from marketing middlemen. However, the manner of influence is not clear. The thir-

teen-member LAC is composed of eight growers, four handlers, and a nonindustry member. The interests of producers and handlers appear similar based on a ranking of returns in table 2. In addition, because at least one of the handler members is from a marketing cooperative, handler interests should closely coincide with those of producers. Middlemen could have offered several reasons to justify a policy movement toward stable shipments. For production-oriented handlers, uniform week-to-week shipments facilitate capacity planning, labor scheduling, ordering materials, budgeting, and shipping. Stable shipments can also help to maintain retail shelf space and service large institutional buyers. This is pure speculation, however, since we have no evidence that middlemen advanced any such arguments.

Hypothesis IV

There was significant growth in the export market for lemons, beginning in 1971–72, especially the Japanese market. Weekly quantities of fresh lemons exported were examined for the 1961–72 and 1974–87 periods, but weekly export prices were not reported by the LAC.[4] Comparison of the weekly pattern of exports with the weekly pattern of domestic fresh sales reveals a similar pattern for each of the two periods. Exports were much higher in the May through September period than in other months during the 1961–72 period, just as were domestic sales. Exports increased throughout the year for the 1974–87 period and seasonal changes became much smaller, with the seasonal pattern of domestic sales and exports again demonstrating a close match. Thus, there was a change toward greater stability of export sales as well as domestic sales 1974–87, and we presume that export prices also became more variable.

Concluding Comments

Various marketing policies can be characterized as orderly marketing but with quite different results for producers, middlemen, and consumers. Estimated returns for California–Arizona fresh lemon sales indicate that constant week-to-week sales may not be consistent with a goal of increasing total returns to producers through use of a prorate program. With varying seasonal demand, a marketing pattern which increased sales when demand was increasing and decreased sales when demand decreased improved total crop returns over those observed with stable sales. The polar case of maintaining a constant FOB price from week to week improved total producer returns over the constant sales case by more than $20 million at the farm level. Middlemen returns, as measured by the marketing margin, varied with the seasonal sales pattern but were highest with constant weekly sales.

Calculated consumer surplus indicated that consumer welfare was greater with a constant average price and varying sales than with constant weekly sales. Thus, given a choice between constant sales or constant prices as an orderly marketing strategy for lemons, both consumers and producers, as a group, would prefer constant prices with quantities shifting in line with seasonal demand. Producers, as a group, can increase their returns by moving away from a constant price strategy and toward a revenue-maximizing sales pattern, but such a move involves reductions in consumer surplus. The term orderly marketing can be interpreted in different ways and can be used to justify either stable sales or stable prices. As shown, the particular marketing policy followed has quite different economic implications for lemon producers (individually and as a group), middlemen, and consumers.

The abrupt and distinct change in lemon marketing patterns that occurred during the mid-1970s is not easily explained by a single hypothesis from among those posed. The timing of the change was related to changes in the relative importance of the three production districts, to changes in the membership of the LAC (which was related to changing production), and to increased lemon exports. The recent pattern of relatively stable sales, when compared with more variable sales, appears to have reduced total returns to District 1 and 2 producers and decreased total consumer surplus while increasing total revenues to District 3 producers and middlemen. Based on our review of the evidence, the changed marketing pattern could not be attributed to any pressure designed to benefit consumers; neither did it appear to result from an expanding export market for fresh lemons. While marketing middlemen may have benefitted from the change, there is little to indicate that they took actions leading to the change.

At this point, the most plausible explanation

[4] Average returns for domestic fresh and export lemon sales are highly correlated on an annual basis, with export returns slightly below those for domestic fresh sales (Kinney et al., pp. 19–20).

for the change in sales patterns relates to regional changes in production and changes in LAC membership. With increased production in Districts 1 and 3, the availability of fresh lemons increased during the period from October through April relative to May through September. The lemon marketing order specifies that the LAC shall give due consideration to the quantity of lemons in storage and lemons on hand (as well as factors affecting demand) when making a recommendation for regulation of shipments. Thus, changing seasonal production patterns would have provided pressure for changing fresh market allocation patterns. At the same time, new LAC members from Districts 1 and 3 might have attempted to increase their share of fresh market sales to increase returns for producers in their districts. This combination of factors appears to account for the rather abrupt change in seasonal marketing patterns for fresh lemons.

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The Strategic Role of Supermarket Buyer Intermediaries in New Product Selection: Implications for Systemwide Efficiency

Edward W. McLaughlin and Vithala R. Rao

Based on logistic regression models that describe the accept/reject decisions of supermarket buyers for new products and market performance of accepted products, the implications for systemwide efficiency of decision making by channel intermediaries are analyzed. The statistical models perform very well. The results point to areas where systemwide performance may be enhanced regarding the allocation of new product development resources. For example, the system may be potentially more efficient if manufacturers reallocate the promotional allowances directed to the retail trade. Better prediction by retail buyers of ultimate product preference by their consumers is likely to increase both firm and system efficiency.

Key words: efficiency, logistic regression, marketing strategy, new products, performance.

Although the management and organizational theory literature is rich in its treatment of internal firm behavior, relatively little of this work has penetrated mainstream economic analysis. This situation is part of the general neglect by economists and agricultural economists of management strategy and conduct, as pointed out by Marion, Leibenstein, Shaffer, among others. To the extent that economic behavior has been studied, however, it has been through the work of industrial organization (IO) economists and, specifically, their work with the structure-conduct-performance (S-C-P) paradigm (e.g., Scherer 1979, 1980). However, Henderson and Marion have noted that IO theory rarely explicitly considers the firm decision environment, either at manufacturer or distributor levels. Recently, several researchers (e.g., Westgren and Cook, Rogers and Caswell) have identified internal firm decision-making and strategic behavior as a high priority research area. Ultimately, if improvements in systemwide efficiency are to be achieved, a better understanding of internal firm decision making is required.

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The Research Context

Increase in new grocery product introductions (alternatively, product proliferation) is an economic phenomenon where a better understanding of firm behavior (conduct) is essential to improving systemwide efficiency. Product proliferation has been widely cited as one of the major modes of competitive conduct by leading grocery manufacturers (Padberg and Westgren, Connor, Zellner). In 1988, estimates of the number of new products, including both fundamentally new products derived from new technologies and line extensions (e.g., new flavors or packages sizes) ranged as high as 10,558 (Gorman). This number is more than twice the 1970–81 annual average (Gorman). The resources required to support this yearly influx of new products are enormous for the entire grocery system. Although aggregate data on costs of new product introductions are not available, selected references on individual product introductions suggest that industry-wide totals are staggering. *Fortune,* for example, reports a total development expenditure of $1.5 billion by the Proctor and Gamble Company to introduce a single product, its Ultra-Pamper diaper, to U.S. supermarkets; $1 billion of this was spent on advertising alone.

Although overall retail store sizes have continued to grow, the relative space allocated to dry groceries has been constant or declining over the last five years (*Progressive Grocer,* Oct. 1987). Wholesale and retail companies simply do not have physical or financial capacity to accommodate all of the the new products, so choices have to be made. Because many products, probably the majority (*Progressive Grocer,* Nov. 1987), do not gain entry into the supermarket system, large economic losses are incurred by manufacturers as well as intermediary firms.

To maximize both distributive efficiency and the probability of new product acceptance, manufacturers require an intimate knowledge of buyers' behavior, not just at consumer levels but at the pivotal channel intermediary (i.e., supermarket buyer) levels as well. Economic theory suggests that manufacturers should make allocations of a predetermined budget for a new product to various components of the new product's marketing plan to equalize marginal returns. To exercise this optimality criterion, manufacturers need better information regarding the characteristics of new products that are most important to buyers in their accept/reject decisions. Further, information is needed on those characteristics of products that are likely to assure consumer acceptance in the marketplace.

Against this background, this paper develops logistic regression models to formalize the channel intermediary's conduct and decision processes regarding new product introductions by manufacturers. The effects of various components of manufacturers' conduct (e.g., marketing strategies) on new product selection decisions are estimated. Further, the status of accepted new products after a period of time was also examined to understand the differences between the intermediary's acceptance and marketplace acceptance. The implications of these analyses for systemwide efficiency are discussed.

Literature Review

Past research of new product introductions may be separated into those with a public policy orientation and those with a managerial perspective. In the former group, the common conceptual theme has been the S-C-P paradigm using secondary sources of data. Some relevant studies in this stream are those by Adams and Yellen, who studied the similarity of new products; Schmalensee, who identified new product proliferation as an explicit manufacturer strategy to erect entry barriers; and Scherer, who estimated the welfare effects of new product introductions. Conner has investigated relationships between manufacturer market structure and the number of new products (for elaboration of these studies, see Connor et al.) As in much of the structure-performance literature, the emphasis on the conduct dimension in these studies, especially of the intermediary-buyer, is minimal.

However, a valuable strain of literature examines new product acceptance from a strategic managerial perspective. Grashof, for example, found that product newness was the most important criterion in a single product category, dog food, when attempting to evaluate the effect of hypothetical product mix on the operating results of supermarkets. Heeler, Kearney, and Mehaffey, in studying a limited data base, concluded that the procurement function could be made more efficient by eliminating those products that did not merit marginal evaluation. Montgomery modeled buyer reaction to hypothetical products; and, while certain of his findings were consistent with a priori expectations—e.g., advertising support was a significant predictor of product acceptability, he pointed to the cumbersome nature of his analytical models for larger data sets.

Thus, past efforts to evaluate new product introductions have relied either on secondary data involving limited numbers of categories, simulated experiments, strictly theoretical approaches, or buyer reaction to hypothetical products. Only modest attempts have been made to investigate the intermediary conduct of the supermarket headquarters buyer. Yet, the strategic decisions made by this link between manufacturer and consumer are key to developing total system efficiency improvement. Finally, the most recent empirical studies (Scherer and Connor) were both conducted on data collected from the 1970s. Given the surge of new products over the past decade and their increasing economic importance, research on this important strategic activity using primary data is required.

Buyer-Seller Conduct

Although various typologies of new products may be cited (e.g., Connor), new products in this paper refer to all items new to the channel intermediary including new flavors, new sizes, and new brands. National brand manufacturers cite

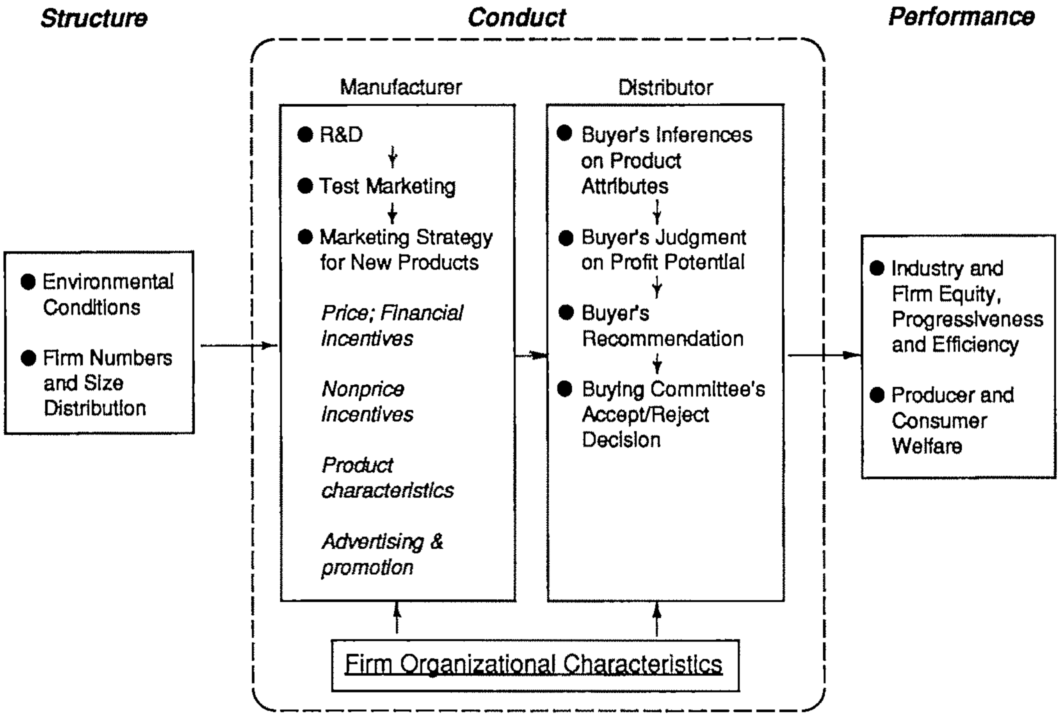
a number of reasons to justify the proliferation of new products, including maintaining interest of channel intermediaries and consumers, extending an item to an adjacent product-space to attract incremental business, taking advantage of new technologies and changes in consumer demand, countering competitive thrusts or preempt competition, transforming a commodity to a higher margin value-added item, and partially ensuring against high new product failure rates.

Despite the key role played by new products in manufacturer marketing strategies, their proliferation imposes considerable costs on other channel members (e.g., wholesalers and retailers) and consumers. Retail organizations, for example, are often attracted to new products by the lure of additional profit opportunities. However, they must also face substantial costs associated with new products. Included are personnel costs in evaluating new products (Hamm), costs of entry and maintenance of new data, and other costs associated with inventory control and handling, specialized wholesale and retail space requirements, and production of shelf signs. Finally, new products may impose substantial direct and indirect costs on consumers. These latter costs come in the form of higher search and information processing costs (e.g., potential confusion regarding new products' characteristics and availability) and higher prices for most new products.

The above discussion points to the importance of the channel intermediary's decision-making process to the performance of the total grocery system. Yet, past research has not shed much light on whether, or in what ways, the intermediary's role enhances or inhibits efficiency. As manufacturers develop new products at a more rapid rate than intermediaries can accommodate them, neoclassical notions of consumer sovereignty initiating efficient decisions may break down if the intermediary becomes the arbiter of consumer choice. Moreover, manufacturer inducements, such as couponing, billing allowances, and free goods, may be more important to the buyer then inherent product quality. These propositions are critical to grocery system resource allocation and efficiency.

The Supermarket Intermediary's Initial Acceptance Model

The conceptual model guiding our analysis of the behavior of the supermarket buyer to accept or reject a new product is presented in figure 1.



Note: Feedback loops not shown here.

Figure 1. Conceptual approach to new product conduct

This approach elaborates the often neglected "black box" or conduct dimension of manufacturer-distributor exchanges, specifically relating to new product behavior. Scherer (1980) suggested that conduct has not received adequate research attention primarily due to the difficulty of quantification and the lack of researcher access to the requisite data. This study attempts to remedy both of these traditional constraints.

Our conduct model implies that a new product's acceptance and, ultimately, system efficiency and performance is a function first of manufacturer and distributor structure (e.g., firm numbers and size distribution), including their organizational characteristics (e.g., chain versus wholesaler), and subsequently of the strategies and decision-making procedures of both sets of firms. For example, subsequent to the generation of a new product idea, a prototype is developed and modified through various phases of R&D activity and consumer research before an initial marketing strategy for the item is established by the manufacturer. The new item may then be presented to the buyer/intermediary. Effectively, the buyer evaluates the new product's likely demand and profit potential (modeling of buyer's judged profit potential has been reported in McLaughlin and Rao) based on the information (e.g., marketing strategy) presented by the manufacturer. The strategy variables typically include price and other financial incentives (e.g., margin structure, credit, forward-buy provisions), promotional factors (e.g., coupons, in-store signage), advertising campaigns, various aspects (e.g., taste, appearance) of the new product and, often, certain nonprice incentives (e.g., free goods, delivery scheduling, slotting allowances).

A number of opportunities for contact and negotiation between manufacturer and distributor occur during this process:[1] distributors may at times initiate the idea of developing a new item with a manufacturer based on perceived market demand; manufacturers sometimes make use of buyer judgment as a proxy for a test market or often share results of any preliminary test marketing for retailer reaction; manufacturers frequently alter certain marketing strategy variables (especially nonprice incentives) based upon the suggestions made by the retailers. Thus, our conceptual model depicts the critical transmittal of information vertically, between manufacturer and retailer (intermediary), as well as the decision making within each firm.

Finally, often after repeated contacts with the supplier, the buyer makes a recommendation to a buying committee. This committee normally consists of senior executives constituted to represent the firm's diverse interests. The buying committee, nearly always acting in accordance with the buyer's recommendation, makes the final decision. This paper models the interaction between manufacturer and retailer (intermediary) that leads to final accept/reject decision.

After review of the above literature and numerous meetings with the participating intermediary, a large number of factors was identified that appear to play influential roles in manufacturers' new product introductions to distributors. In table 1, the relevant variables are grouped into four categories: financial, competition, marketing strategy, and other. These variables are, in effect, both the objective and subjective measures of conduct—the give-and-take negotiation process—between manufacturer and distributor suggested in figure 1.[2] Further, we have hypothesized the direction of influence of each variable on the intermediary's decision to accept a new product; the reasoning behind most of those hypotheses is straightforward. However, brief explanations are provided below.

Of the financial factors, the gross margin and profit variables are hypothesized, with some uncertainty, to have a weakly positive effect on product acceptance. Gross margin may be set at high levels to cover required, but perhaps burdensome, tasks to be performed by retailers. In these cases, high gross margins may negatively influence new product acceptance because a high gross margin may not yield a high profit. Similarly, a high profit level may indicate a high price that could dampen consumer demand making the product less acceptable to distributors. The final financial factor, the opportunity cost variable, is expected to have a negative influence on buyer's likelihood to accept a new product the greater the minimum dollars required to order the product.

Competition was broken into two parts: firms and brands. The "firms" variable measures the number of competing distributor firms which al-

[1] Distributor is a term used interchangeably to refer to both wholesale and retail intermediaries. As a chain store organization, the intermediary participating in the empirical part of this research performs both these functions.

[2] Our specification of this conduct model may in fact capture the effects of certain structural variables. For example, the effect of size of manufacturer is partially accounted for by the measures of vendor effort and several of the terms of trade variables.

Table 1. Variables, Operationalization, Specific Measures, and Hypotheses

Category	Variable	Measure(s)	Hypothesized Influence on Buying Decision
Financial	Gross margin	Percentage gross margin	Positive (?)
	Profit	$ profit per cu. ft. of shelf volume	Positive (?)
	Opportunity cost	Dollars needed to meet min. order quantity	Negative
Competition	Firms	Actual buyer determination of numbers of firms and brands	Positive
	Brands		Negative
Marketing strategy	Product uniqueness (quality and package)	Buyer judgments on 0–10 scales (sum)	Positive
	Vendor effort	Buyer judgments on 0–10 scales (sum)	Positive
	Marketing support	Three categories—none, partial, and high support	Positive
	Term of trade	Presence or absence of off-invoice, slotting allowances, bill back and free cases	Positive or negative
	Price	Two dummy variables for low and medium prices	Positive (?)
Other	Category growth	Index of buyer judgments on 0–10 scales	Positive
	Synergy	Whether item is a member of a family (0,1)	Negative

ready carry this item, and the "brands" variable measures the number of competing manufacturer brands carried by the distributor. We hypothesized a positive relationship between the firms variable and buyer acceptance. In essence, a vigilant buyer is likely to be favorably influenced by a positive evaluation of the new item by a competing firm. On the other hand, we hypothesized that the likelihood of buyer acceptance decreased as the number of existing national brands and private label products that competed for limited shelf space with this item increased.

We developed a series of measures to describe manufacturers marketing strategies. Generally, we expected positive relationships with these strategy variables under the control of the vendor. For example, we expected that, as the score on product uniqueness (that is, a composite variable combining buyer judgments of product quality, performance, and package design) increased, buyers would be more likely to accept the product. Similarly, we expected as marketing support increased from "none" (no T.V. or coupons) to "partial" (either T.V. or coupons) to "high" (T.V. and coupons) that buyer acceptance would also increase. The reasoning for the other strategy variables was similar except for bill back provisions. Many retailers find it cumbersome to "bill back" the manufacturer for allowances after having complied with certain performance requirements. The transaction costs of the paperwork are not trivial. Hence, we hypothesized that this particular term of trade would negatively influence acceptance.

Finally, new products in fast growing product categories are expected to be accepted with higher probabilities by channel intermediaries. A new item's synergy, the association with a family of existing products, is hypothesized generally to reduce acceptance probability. The reasoning again was based on physical space limitation: intermediaries are less likely to add line extensions to existing products. However, the strength of this relationship naturally depends upon the distributor's prior experience with the parent line.

Since the choice variable is dichotomous (accept or reject), the acceptance probability for a new product can be modeled by the familiar logistic function:

$$(1) \qquad P_j = \frac{1}{1 + \exp(-\alpha - \underset{\sim}{\beta}'\underset{\sim}{X}_j)},$$

where P_j is the probability of acceptance of the jth item by the channel intermediary, $\underset{\sim}{X}_j$ is a ($p \times 1$) vector of descriptors measured for the jth item, $\underset{\sim}{\beta}$ is a ($p \times 1$) vector of parameters, and α is an intercept term.

The logistic regression model in equation (1) is estimated by maximum likelihood methods, using the LOGIST procedure developed by Walker and Duncan and implemented in the SAS package (Harrell).

Empirical Study

In accordance with the conceptual model of manufacturer-distributor conduct, data were collected from a large supermarket chain chosen to exemplify the typical organization for evaluating new products. The chain is publicly held, covers a large trading area with approximately 100 stores in the northeastern United States, and its 1988 sales approached $1 billion. The chain's headquarters region is frequently employed by manufacturers for test marketing because of the representativeness of its consumer profiles and market area. It is highly unlikely that any food manufacturer would bypass this firm in the introduction of a new product. Hence, although the model applies only to one company, the representativeness of the firm may permit a cautious generalization of the results to other market conditions.

Two types of primary data were collected from the chain: (*a*) vendor-supplied materials including product physical characteristics (e.g., case cubic dimensions), financial information (e.g., suggested retail price, gross margin), and promotional support (e.g., television ads, couponing), and (*b*) a one-page questionnaire completed by each buyer assessing his/her judgments of qualitative attributes (e.g., taste, quality, performance) for every new item. Several variables employed in the model were computed from the data (see table 1). The data were collected for about 2,000 products on a weekly basis from June 1986 to February 1987. These new items belonged to more than 25 product categories based on the retail trade classification system of *New Product News* (Gorman).

Intermediary's Acceptance Rates

The overall acceptance rate for new products presented to this chain was 29.0%. However, significant variation exists in the rates of acceptance by product category (e.g., at the extremes, 21% for canned foods to 61% for pet products) and by suggested retail price of the item (27% for items priced less than $1.00 to 39% for items over $2.00). Further, consistent with prior expectations, acceptance rate steadily grew as the levels of marketing or promotional support (television advertising and coupons) increased: 24% of products with no promotional support were accepted, 41% with limited support (either coupons or TV), and 46% with high levels (coupons and TV) of promotional support.

Some past studies (e.g., Connor) suggest that total promotional support is generally highly correlated with the size of the firm offering the new product to the channel. Additional data on manufacturer size, using total sales as a measure, were collected using the sources of Moody's industrial manuals, Standard and Poor's stock reports and Ward's directories. This effort yielded complete data for over 75% of the new products and over 80% of the firms involved. For the available data, the acceptance rate was 41.3% for firms with annual sales over $700 million, 28.6% for firms with sales between $2 million and $700 million, and 29.2% for firms with sales under $2 million. Thus, results from past studies were corroborated for the largest firm category but were less consistent for the smaller firm categories.

Analysis Method

Unfortunately, nearly 50% of the collected data were not analyzed in this model because some of the variables were incomplete. However, a sample of the product profiles from the incomplete data set was analyzed and was not significantly different from the profiles in the complete data set. The complete data were divided randomly into two subsamples for analysis and validation; the validation data constituted about one-third of the total sample. The major analysis consisted of building logistic regression models for all categories of items, for subgroups of items with several levels of marketing support, and for groups of items of different price ranges. Analyses for subgroups of items were conducted to account for the inherent heterogeneity among the various categories of products. In all of these models, the product category variations are accounted for by a set of dummy variables.

Results

The logistic regression model fits the data well. The predictive accuracy exceeds 78%, much higher than that expected by chance. Additionally, the model correctly predicted 72% of the decisions in the validation sample.

The estimated coefficients for the variables for the logistic model for the total analysis sample are shown in table 2. The model chi-square

Table 2. Results of Logistic Regression for Total Sample (Accept/Reject Decisions)

Group of Items Variable	All Items
Intercept	−5.47 (41.92)*[c]
Gross margin	−0.06 (10.30)*
Profit per shelf volume	0.004 (3.24)+
Opportunity cost	−0.001 (1.14)+
Number of competing firms	0.14 (11.72)*+
Number of competing brands	−0.03 (1.89)*
Product uniqueness (quality)	0.25 (18.03)*+
Vendor effort[a]	.03 (0.46)+
Terms of trade dummies:	
Off-invoice	−0.19 (0.70)
Slotting allowance	−0.43 (2.03)
Bill back	−0.93 (6.04)*+
Free cases	−0.22 (0.87)
Low-price dummy	−0.17 (0.30)
Medium-price dummy	0.02 (0.01)+
Expected category growth	0.68 (46.49)*+
Synergy dummy	−0.31 (2.01)+
Product category dummies[b]	(not shown)
Number of observations	687
Model Chi-square, D.F.	249.49, 23
P-Value	0.0

Note: Entries are coefficient and chi-square for each variable (with 1 d.f.).
[a] The marketing support variable is in this buyer judgmental variable.
[b] The relative differences on estimated acceptance probability of product categories are shown in table 4.
[c] Single asterisk indicates significant at 0.05 level; plus sign indicates sign of the coefficient is according to expectations.

is highly significant. Further, the coefficients of the majority of the variables are in the predicted direction. The variables of product uniqueness, expected category growth, and number of competing retail firms show postitive and significant effects. The variable bill-back terms of trade shows a negative and significant effect. These results are consistent with our hypotheses for the model. The only significant variable with a sign contrary to the hypotheses is gross margin for which we had hypothesized a weak positive relationship. This finding is consistent with similar results of Montgomery, however, who found a negative but not significant relationship between new product acceptance and gross margin. The only other variables that appear with contradictory signs were the remaining terms of trade factors, but their coefficients are not statistically significant.

Model Structure for Subgroups

The logistic model was also estimated for subgroups of items—by marketing support and by price. The model chi-square statistics are uniformly high. As could be expected, the classification accuracy (not shown here) improved for the various subgroups of items (resulting from greater homogeneity within a subgroup). For brevity, only the significant variables and their direction are shown in table 3 for these subgroup models.

The subgroup models revealed a number of differences from the overall model. First, for low-priced items, as the intensity of vendor effort and profit per shelf volume increase, the probability of acceptance increases. Second, for medium and high price items, gross margin, vendor effort, and profit per volume cease to have significant influences on the accept/reject decision; however, both product quality uniqueness and expected category growth show positive significant influences. In addition, the synergy dummy has a negative significant effect for high-priced items. Third, product uniqueness measure is the only significant variable common to both highly supported and unsupported items. For highly supported items, opportunity costs (negative), expected category growth (positive), and both price dummies (negative) are significant; while for unsupported items, gross margin (negative), number of competing firms (positive), and vendor effort (positive) are significant indicators.

Considerable variation occurs in the acceptance of new products by product category as presented in table 4. In the sample as a whole, empirical acceptance rates are much higher for the categories of candy and gum, sauces, etc., and snacks, crackers, and nuts. Table 4 also shows the estimated probabilities of new product acceptance for items comparable on all aspects but the product category for all items and for each subgroup of items. These estimates were calculated using a base of .33 for the "other" category, essentially to control for all aspects of the new item except the product category. Thus, they indicate the "true" differences among the product categories. These data show that for all items, household supplies and dairy foods have the lowest acceptance probabilities and items from

Table 3. Significant Variables for Logistic Regression for Selected Subgroups of Items (Accept/Reject Decisions)

Subgroup of Items	Significant Variables	Sign of Relationship	Number of Observations	Model Chi-Square; D-F, P-Value
Low-priced items ≤$1.00	Gross margin	−	237	90.61; 21
	Profit/shelf volume	+		0.0
	Vendor effort	+		
Medium-priced items $1.00–$2.00	Number of competing firms	+	289	128.06; 21
	Product uniqueness	+		0.0
	Slotting allowances	−		
	Bill back	−		
	Expected category growth	+		
High-priced items ≥$2.00	Number of competing firms	+	161	117.75; 21
	Product uniqueness	+		0.0
	Expected category growth	+		
	Synergy dummy	−		
Unsupported items	Gross margin	−	194	120.87, 23
	Number of competing firms	+		0.0
	Product uniqueness	+		
	Vendor effort	+		
Highly supported	Opportunity cost	−	155	95.61; 23
	Product uniqueness	+		0.0
	Low price dummy	−		
	Medium price dummy	−		
	Expected category growth	+		

Note: Price variable was described by three categories shown above, and dummy variables were used in the model for the low and medium categories.

the candy and gum group have the highest acceptances. The rankings of categories change when subgroups of items are examined. For example, for the highly supported items, dairy foods receive a much higher acceptance while candy and gum continue to enjoy highest acceptance. Other interesting differences include a nonmonotonic relationship between acceptance probability and price of the new item for such categories as frozen foods, canned foods and sauces, spices, etc.

Finally, the coefficients of the models by firm size (not shown here) reveal notable differences in the slotting allowance variable. This variable

Table 4. Product Category-Specific Probabilities in the Logistic Models of Accept/Reject Decisions

		Illustrative Acceptance Probabilities for Comparable Items for					
Product Categories	Empirical Acceptance Rate (%)	All Items	Unsupported Items	Highly Supported Items	Low-Priced Items	Medium-Priced Items	High-Priced Items
Frozen foods	33.0	0.133	0.011	0.084	0.395	0.035	0.084
Canned foods	21.1	0.208	0.053	0.411	0.463	0.096	0.510
Dairy foods	28.0	0.098	0.002	0.453	0.228	0.010	0.080
Beverages	28.3	0.112	0.296	0.000[a]	0.000[a]	0.180	0.096
Household supplies	29.1	0.066	0.006	0.000[a]	0.024	0.035	0.018
Sauces, spices	43.8	0.174	0.147	0.397	0.550	0.040	0.451
Candy & gum	43.4	0.390	0.053	0.772	0.606	0.143	0.244
Snacks, crackers & nuts	43.4	0.165	0.059	0.110	0.001	0.112	0.086
Others	28.2	0.330	0.330	0.330	0.330	0.330	0.330

[a] These estimates are very close to zero because of a very large (but insignificant) coefficient for the dummy variable of the corresponding product category.

was positive and significant for firms with total sales under $2 million but negative and significant for firms with sales between $100 million and $700 million. Interestingly, however, the variable is insignificant for firms larger than $700 million in sales.

Buyer Adaptation to Consumer (Market) Response

The modeling results reported above describe the linkage between certain manufacturer strategies and supermarket buyer acceptance. However, to better understand the relationship of the buyer as the channel intermediary between the manufacturer and the consumer (or marketplace), additional data were collected from the participating retail firm on the status of the subset of all products accepted from the original set of products presented by vendors. Table 5 reports the status for these 549 products (29%). Out of the 549 accepted products, 31.9% (175 products) or 9.2% of the original sample presented, were still on the retail shelves selling well nearly two years after the initial vendor presentation. Although 69.1% of the products initially accepted by the buying organization were discontinued within the first two years, buyers reported a variety of reasons for this deletion decision. The three categories buyers most often cited were lack of consumer interest (45.3% of all deletions), expiration of manufacturer introductory allowances (12.9%), and the introduction of a superior competing item (11.5%).

Table 5 also shows the profile of attributes present in the set of products initially accepted by the buying committee as compared to the profile of attributes (variables) of the products that had ultimately been "accepted" by consumers (or by the market) after two years.[3] These comparisons show numerous differences between the attributes present in the group of products accepted by the buyer/intermediaries (buyer acceptance) and the group of products ultimately accepted by the marketplace (consumer acceptance).

The last column in table 5 is an index of the approximate efficiency with which the buying committee was able to predict consumer acceptance computed as the ratio of percent of products accepted by the buying committee and the percent of products "accepted" by consumers in the marketplace after two years. Thus, this ratio is an approximate measure of the degree to which the buying committee (in the role of an agent for consumers) and consumers evaluate new products in an equivalent mannner. A score of 1.00 indicates that buyers were able to perfectly anticipate consumer's final judgment with respect to the importance of the selected attribute. An index greater (less) than 1.00 suggests that buyers "overestimated" ("underestimated") the importance of an attribute, at least as determined by the proportion of all the products ultimately accepted by the marketplace that exhibit this attribute. For example, of all products accepted by the buying committee, 21.7% had test market results presented to buyers as a part of vendors' new product presentation; however, 28.0% of the successful products (i.e., still on shelves after two years) were those that had had such test market results originally presented. The resulting index, .78, suggests that buyers underestimated the importance of test market results in determining ultimate marketplace success.

The attributes for which the index is either very large or very small are pictorially shown in figure 2. For example, products given high scores on product uniqueness by buyers do not necessarily gain consumer acceptance to the same degree (the index is 1.24 showing the possible inefficiency of the buying committee to predict consumer acceptance).

Systemwide Efficiency Implications

Although new product introductions have been widely cited as one of the major modes of conduct by grocery manufacturers, new products are likely to be an equally important strategic tool of distributors as well. Yet, little research has probed the conduct of the retail buying teams, gatekeepers to the supermarket shelves, regarding how they decide to accept or reject the growing number of new product offerings. The statistical model developed in this paper estimated the importance of the various components of a manufacturer's new product strategy in determining the acceptance of a new product by an individual supermarket intermediary. With knowledge of manufacturer new product budgets, these results can be used in the calculation of marginal returns associated with various marketing mix factors and optimum levels and al-

[3] A logistic regression model was also developed to examine the ability of the same set of variables used in table 2 to predict the status (consumer acceptance) of the accepted products after two years. This model predicted correctly 73.5% of the time (less than the buyer acceptance model), and there was no overlap between the two sets of significant variables.

Table 5. Profiles of New Products Accepted by Buying Committee Versus Accepted by Consumers (Marketplace), Two Years After Introduction, by Major Attribute

Variable/Attribute	Products Introduced Total	Buying Committee Acceptance	Consumer (Market) Acceptance	Index of Buying Committee Acceptance to Consumer Acceptance
Number of products	1,899	549 (29.0%)	175 (31.9%)	0.91
Test market results presented	322	21.7%	28.0%	0.78
Market research data presented	642	46.3	46.3	1.00
Terms of Trade				
Slotting allowances offered	258	14.2	10.3	1.38
Off invoice allowance offered	1,186	68.5	70.3	0.97
Free cases offered	501	27.9	30.9	0.90
Bill back provisions	204	8.9	10.9	0.82
Financial				
Profit/cube ≦ $3.00	1,218	56.1	61.1	0.92
Profit/cube > $3.00	681	43.9	38.9	1.13
Opportunity cost < $1000	1,101	64.3	65.7	0.98
Opp. cost $1,000–$10,000	596	25.1	20.0	1.26
Opp. cost > $10,000	202	10.6	14.3	0.74
Gross margin < 14%	403	18.8	20.0	0.94
Gross margin 14%–24%	441	27.9	27.4	1.02
Gross margin > 24%	1,054	53.4	52.6	1.02
Competition				
No. competing firms = 0	984	50.5	45.7	1.10
No. competing firms = 1–6	367	18.9	21.7	0.87
No. competing firms > 6	547	30.6	32.6	0.94
No. competing brands = 0	975	58.7	57.1	1.03
No. competing brands > 5	924	41.4	42.9	0.96
Product characteristics				
Uniqueness ≦ 12	1,159	39.0	36.6	1.07
Uniqueness 13–14	449	32.6	40.6	0.80
Uniqueness ≧ 15	291	28.4	22.9	1.24
Vendor effort ≦ 10	1,039	35.3	34.9	1.01
Vendor effort 11–13	604	37.5	35.4	1.06
Vendor effort ≧ 14	256	27.1	29.7	0.91
Retail price < $1	830	36.8	39.4	0.93
Retail price $1–$2	648	33.5	37.7	0.89
Retail price > $2	421	29.7	22.9	1.30
Categ. growth ≦ 5	848	17.5	14.3	1.22
Categ. growth ≧ 6	1,051	82.5	85.7	0.96
Synergy (related to existing products)	1,071	50.8	52.0	0.98
Product categories:				
Frozen foods	385	22.5	26.4	0.85
Canned foods	241	8.2	8.1	1.02
Dairy foods	207	8.2	10.3	0.80
Beverages	184	8.2	4.0	2.05
Household supplies	110	4.6	8.1	0.57
Sauces, spices, etc.	104	7.1	5.8	1.24
Candy & gum	116	9.5	5.2	1.84
Snacks, crackers, etc.	87	3.3	4.0	0.82
Other	700	28.3	28.2	1.01

location of manufacturer expenditures. When the optimal decisions are implemented, systemwide efficiency increases: profits can be higher for channel members and at the same time prices can be lower for consumers.

The lack of significant positive effects of certain terms of trade (e.g., slotting allowance and free cases) and, indeed, the significant negative effect of others (e.g., bill back provisions) have several implications for total food system efficiency. Although this result appears contrary t certain of the conduct-model's prior expecta tions and contrary to much popular industry per ception (see, for example, *Supermarket New* and *New York Times*), a possible hypothesis i that the presence of certain nonprice incentives like slotting allowances, may be correlated wit inferior products. That is, suppliers may offe additional support for products they fear are no truly unique and, similarly, buyers may indee

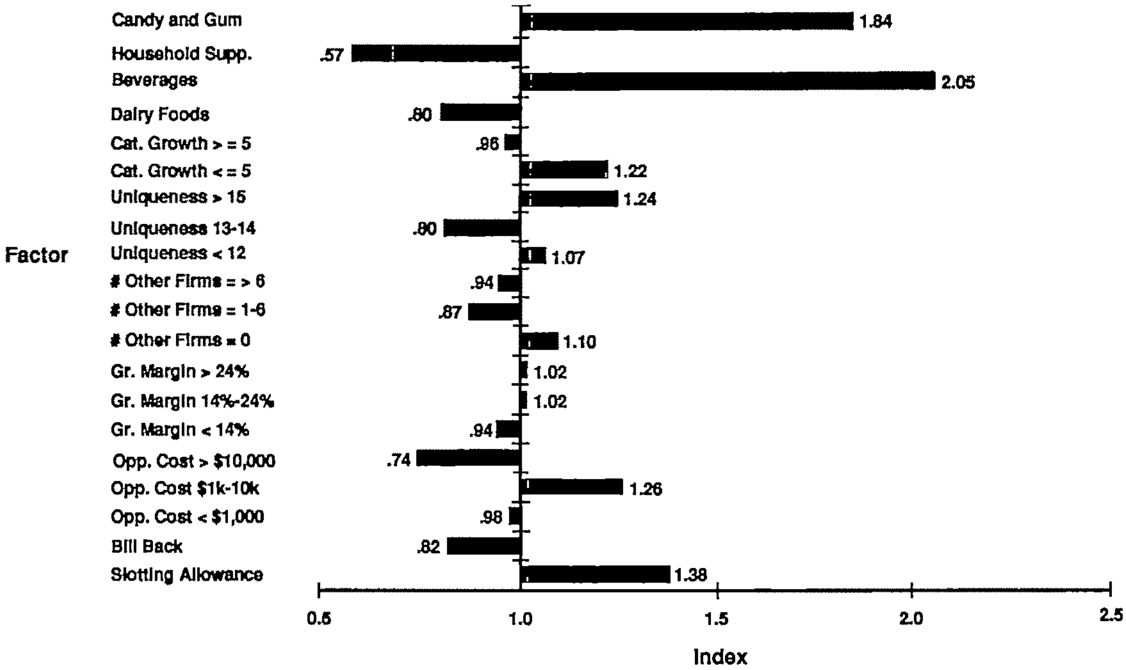


Figure 2. Index of relative factor importance, buyer vs. consumer

recognize and accept truly superior products on their own merits without requiring additional inducements. In fact, when the buyers in the participating retail firm were confronted with this initially puzzling result, they corroborated that the hypothesis accurately described typical industry practice. Moreover, the attribute profile of products that had withstood the test of the marketplace—those selling well after two years—suggests that buyers apparently "overestimated" the importance of the slotting allowances (index = 1.38). This finding also suggests that buyers may initially accept products that are accompanied by slotting allowances, perhaps because of the financial incentive alone, only to discontinue them relatively sooner than competing new items without allowances.

Thus, the implication is that much of the large and currently expanding manufacturer promotional allowances directed to the retail trade may be inefficient if not redundant. This study indicates that manufacturers may be better off by reallocating some of their new product budgets into activities more likely to influence positively both buyers and consumers. However, this is not an easy prescription because, as this analysis has shown, several of the strategy variables that are most influential to buyers (e.g., product uniqueness and category growth) are apparently not weighted as heavily by consumers. That is, retail buyers base new product decisions, at least in part, on a different set of criteria than consumers. Better prediction by retail buyers of ultimate product preference by their consumers is likely to increase both firm (and system) efficiency.

Data collection efforts in this research were somewhat disappointing because various pieces of information were missing (e.g., number of coupons, dollar amounts of advertising, etc.) for a number of items. This is not just a researcher problem; it is also a problem for channel intermediaries in their actual decision-making environments. It appears likely that information from vendors could be much improved by including, and perhaps even standardizing, advertising and promotional materials, the format for discounting schedules, etc., in new product packets. Although some vendors may not initially embrace such a proposal because they fear loss of competitive advantage, overall results would eliminate duplication and waste, thus increasing the efficiency of the entire system.

Finally, our data show that a higher percentage of products were accepted when market research results were presented (39% of products with test marketing or marketing research results were accepted versus 28% acceptance rate for products without these results). As a result, one could hypothesize that, given the high mar-

keting costs of test marketing a new item with consumers, manufacturers instead simply introduce the item to the buyer first. The buyer frequently is in a better position to assess potential consumer demand than a manufacturer. Thus, this procedure may serve as a quick and inexpensive market test. In this sense, recent large numbers of new product introductions may not represent inefficient product proliferation but an efficient manufacturer strategy to increase variety (and profit) while reducing systemwide costs.

Future Research Directions

We are encouraged, based on this research experience with one company, that a richer complement of conduct or strategic variables can be incorporated into economic analysis to improve systemwide efficiency and performance. Further investigation is warranted into the idea that buyers and consumers may use different sets of variables in evaluating new products.

While the empirical approach utilized in this paper has enabled us to describe the judgmental processes of a retail buyer, arguments can be made that we seek a theoretical foundation for the estimated model. The development of a model based on microeconomic theory in which an intermediary's decision to add a new product as one of maximizing the utility of the retail firm could be a worthwhile pursuit. Such a model may include such theoretical constructs as product quality, organizational innovativeness, and competitive advantage, which can directly lead to specification of variables to be included in an analytical model for estimation.

One obvious direction of future research is to replicate this research to additional firms to probe such questions as: Why do certain firms choose particular organizational forms to evaluate new products? What is the impact of these other forms (e.g., no committee) on the acceptance rates? Are some forms more (less) efficient or more (less) beneficial for producers or consumers? Which organizational forms enhance the success of manufacturer strategies? It might be shown, for example, that a reorganization of a distributor's buying process could result in lowering a firm's transaction costs and a probable improvement in system welfare.

An ideal next step in this research stream is to develop a societal balance sheet of costs and benefits coming from the new product introduction activity in the food system. Various measurement questions arise in this endeavor. From the manufacturer's perspective, not only are assessments of costs of R&D and marketing effort needed but so are the opportunity costs of false introductions and early dismissal of likely successes. Further, the importance of new products for the viability of the firms should be measured in monetary terms. Similar costs and benefits can be identified at the intermediary level. While one can debate the existence of any consumer benefits at all from new product proliferation, ample research opportunities are available to increase the efficiency of the process.

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Simulation Modeling to Set Priorities for Research on Oyster Production

Darrell J. Bosch and Leonard A. Shabman

Private oyster production in Virginia has declined significantly because of factors including losses from MSX (*Haplosporidium nelsoni*). Increased state and federal funding is being proposed to support research to stimulate oyster productivity. A model of oyster production under uncertainty, including growth, disease, and economic components, is used to aid in setting research priorities. The model shows effects of different types of research information on returns to a representative oyster planting enterprise. Seed harvest technology and accurate knowledge of the salinity threshold at which MSX mortalities occur are found to have greatest promise for increasing profitability of oyster production.

Key words: bioeconomic model, economic returns, MSX, oyster planting, research priorities, seed costs, uncertainty.

Encouraging increased oyster planting on privately leased shellfish beds is a priority of the Commonwealth of Virginia, which is seeking to reverse a long-term decline in private oyster production from 3.65 million bushels in 1956 to 0.58 million bushels in 1986 [Virginia Marine Resources Commission (VMRC) 1979 and 1988]. The factors that are asserted to be primarily responsible for the decline are the disease *Haplosporidium nelsoni* (MSX), which first appeared in the area in 1959 and the continuing inability to develop planting strategies to avoid disease losses (Haven, Hargis, and Kendall; VMRC 1986). The state has proposed increased funding for oyster production research (VMRC 1986). At the federal level, a 1988 bill proposed $68 million to fund ten years of oyster production research (U.S. Congress, House). The result for 1989 is a federal appropriation of $500,000 (U.S. Congress). The strategic decision to increase funding for oyster production research must now be followed by setting of priorities for areas of study within an overall research budget. The objective of this study is to evaluate economic returns to alternative types of oyster production research. A bioeconomic simulation model of oyster production is used to evaluate the effects of alternative types of research information on the returns from oyster production. Model results are used to recommend research priorities to increase productivity in the oyster industry.

Background on Oyster Production

Planting of oysters is an aquacultural enterprise in which immature oysters, called seed, are planted on the bottom of saline rivers and bays and allowed to mature to market size. The time to maturity is correlated with the salinity of the overlying waters. Up to a point, salinity is positively related to the growth rate of the seed because it is associated with a wide range of favorable growing conditions (Kennedy and Breisch). Growth rates approach zero at salinity levels below five parts per thousand (ppt), with maximum growth rates at salinity levels above twelve to thirteen ppt (Loosanoff, Chanley).

Although growth rates increase in a predictable way with higher salinity, higher salinities also increase the potential for significant mortalities from MSX disease (Haven, Hargis, and Kendall). Disease behavior is also seasonal as initial infection can occur during May through

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October and only if salinities in those months are at a trigger level. After an incubation period and in the presence of threshold salinities higher than the trigger salinities, mortality will occur until the onset of colder water temperatures of winter (Andrews). MSX infection reduces oyster yields and lowers oyster condition indices (Haven, Hargis, and Kendall). However, MSX infection poses no danger to humans, and infected oysters can be marketed.

Despite the general understanding of MSX behavior and its relationship to salinity, important specific relationships have not been precisely identified. First, the salinity level that triggers infection is not known with certainty but is expected to range between fifteen and twenty-five ppt (Andrews). Second, the incubation period from infection to mortality is not known. Third, the threshold salinity that induces mortality is equal to or greater than that which results in infection and probably varies between fifteen and twenty-five ppt (Andrews), but the precise threshold is not known with certainty.

Oyster planters choose a grounds location for seed planting in recognition of the trade-off between salinity-associated growth and disease potential. To illustrate, seed costs of up to $4,000 per acre might be incurred to plant 1,000 bushels of seed. Once the oysters are planted, favorable salinity patterns may result in a 1,000 bushel market oyster harvest (a 1 : 1 seed-harvest ratio) with a market value of $12,000. Harvest would occur over a short period at some point two to four years after planting. However, if salinity rises enough to result in disease outbreaks, the initial $4,000 might be lost; conversely, unfavorably low salinities might delay the date of harvest. Clearly, the returns from oyster planting are risky and greatly affected by the choice of planting location. However, grounds availability is not a production constraint because much of the private oyster grounds in the state are currently barren (VMRC 1986).

Oyster researchers have called for studies to improve the understanding of the relationships between salinity and MSX and for the development of techniques for faster disease diagnosis (Ford, Perkins). Such research might permit planters to select grounds with expected salinity high enough to maximize growth rates but without the risk of MSX loss. If disease does occur, faster disease diagnosis might help to save most of the crop.

Even perfect information about the correlation between MSX disease and salinity would not remove planting risk because salinity cannot be known at planting time. Rather, the salinity pattern depends upon streamflows, which in turn depend upon unpredictable weather patterns. The only way to fully remove disease risk would be to plant a disease-resistant oyster (Ford, Perkins).

In addition to MSX disease, economic factors also explain the decline of private oyster production. Specifically, the real price of seed oysters has increased far more rapidly than market oyster prices (JLARC, Shabman and Thunberg). From 1964 to 1987, market oyster prices approximately doubled, while nominal seed prices increased from $1.34 per bushel to $3.06 per bushel. Interviews with private planters indicate that the number of seed per bushel has significantly declined over the period, meaning that real seed costs have increased even more. Thus, another research area might be ways to produce seed at lower cost.

Simulating the Contribution of Research Information to Oyster Planting

A simulation model was developed to evaluate how different types of research information might improve the risk efficiency (reduce the variance and/or increase the expected returns) of private oyster planting and thereby increase private planting. The effect of research information on the risk efficiency of planting was simulated by varying the most uncertain model parameters and determining improvements in risk efficiency of planting with better information. The model was applied to the Rappahannock River in Virginia, the primary private oyster production area in the state.

A representative oyster planter is expected to seek a favorable distribution of net present values (*NPV*'s) of returns from oyster production at some specific river location. The *NPV* from a single crop with a given salinity pattern over the growing cycle is calculated as shown in equation (1).

$$(1)\quad NPV = Y(P - HC)/(1 + r)^n - (SC + T + SP)(SD),$$

where Y is the number of bushels harvested from the enterprise, P is the per-bushel harvest price, HC is the per-bushel harvest cost including delivery to the market location, r is the real monthly before-tax discount rate, and n is the number of

months from planting to harvest;[1] SC is the per-bushel seed purchase price, T is the tax levied by VMRC on each bushel of seed purchased, SP is the seed planting cost, and SD is the number of bushels of seed planted;[2] Y, which depends on disease losses, and n, which depends on growth rates, are salinity dependent. The planter is assumed to be a price taker (Shabman and Thunberg, JLARC). Parameter values used to estimate net returns are shown in table 1.

The oyster enterprise model is summarized in figure 1.[3] Initially, a planting location, year, and month are selected. Planting cannot occur in July, August, or September because of unavailability of seed. After planting, monthly salinity is established based on location and lagged streamflow. The relationship between streamflow, location, and salinity was estimated using salinity measurements collected at various locations in the Rappahannock River from 1970 to 1983 (Virginia Institute of Marine Science) and daily streamflow measurements available through the Hydrologic Information Storage and Retrieval System (HISARS) administered by the Virginia Water Resources Research Center. The estimated model based on 535 observations is the following (t-statistics are in parentheses):

$$(2)\quad \begin{aligned} S = {} & \underset{(96.78)}{19.588} - \underset{(-55.60)}{0.00251658K^2} - \underset{(-3.63)}{0.209454SF1} + \underset{(5.73)}{0.0000002SF1^2} - \underset{(-7.79)}{0.1732264SF2} \\ & - \underset{(-6.08)}{0.1328310SF3} + \underset{(2.15)}{0.0119554KT} \quad R^2 = .87, \end{aligned}$$

where S is estimated salinity in ppt; K is kilometers (km) from the river mouth; $SF1$, $SF2$, and $SF3$ are the sums of daily streamflow readings (in 10,000s of cubic feet per second) for 0 to 30, 31 to 60, and 61 to 90 days, respectively, preceding the salinity measurement; and T is a dummy variable that takes a value of 1 for high tide and 0 for low tide. The coefficients have the expected sign with salinity decreasing as streamflow and distance from the river mouth increase.

Oyster growth is related to season, salinity, and size as shown in the following equation, which is based in part on studies by Askew (1972, 1975, 1978):

$$(3)\qquad W_t = W_0 e^{a_t b_j c_k},$$

where W_t is the oyster's weight at the end of month t, W_0 is the weight at the beginning of month t, e is the base of natural logarithms, and a_t represents the seasonal parameter. The fastest growth rates are realized in late spring and early summer and the slowest growth rates occur in winter. The a_t values were calibrated using data from Virginia oyster growth studies (Andrews, unpublished data, Virginia Institute of Marine Science).

The parameter b_j was included to represent salinity effects because of the recognized relationship between grounds production potential and salinity (Haven, Hargis, and Kendall; Kennedy and Breisch). These parameter values were derived with the help of scientists at the Virginia Institute of Marine Science (VIMS) and oyster producers. They were asked about the length of time required to produce a three-inch oyster from a one-inch seed in the Rappahannock River on grounds of varying salinity. They indicated that two years are required for salinity levels greater than thirteen parts per thousand (ppt), three years for salinity levels between ten and thirteen ppt, and four years for salinity levels between six and ten ppt. No growth occurs for salinity levels less than six ppt. Values of b_j that would cause these growth rates to be achieved were solved for iteratively.

The instantaneous annual growth rate that depends on the oyster's weight k at the beginning of the season is represented by c_k. The growth rate declines as oyster size increases. The values for c_k were based upon relationships derived by McHugh and Andrews for Chesapeake Bay oysters.

Oyster mortality is also calculated each month. Two sources of mortality considered are salinity-independent background factors, which include losses to predation and smothering by silt,

[1] Harvest cost is constant at $4.54 per bushel, based on estimates obtained in planter interviews in the Rappahannock River area in April 1988. Planters noted that costs, particularly for hand tong harvest, increase when oysters are less dense on the bottoms. However, with lower density, planters are more likely to use a mechanical dredge for harvest, which lowers costs compared with hand tong harvest.

[2] Most private grounds in the river are currently barren. Consequently, the planter, whose expectations as to salinity level at a given location change, is more likely to vary locations than to vary the amount of seed planted at a given location.

[3] Average costs are not affected by location; therefore, optimal enterprise size need not vary by planting location and a constant enterprise size of 1,000 bushels is evaluated for all planting locations.

Table 1. Economic and Physical Production Parameters Used in Oyster Enterprise Model

Parameter	Value	Parameter[a]	Value
			($/bu.)
Seed count/bu.[b]	600	Jan. price	10.21
Seed size (in.)	1.5	Feb. price	11.67
Seed price ($/bu.)[c]	3.06	Mar. price	11.81
Seed tax ($/bu.)	0.15	Apr. price	12.57
Planting cost ($/bu.)	2.08	May price	13.75
Transplanting cost ($/bu.)[d]	5.84	June price	11.30
Harvest cost ($/bu.)	4.54	Jul. price	13.33
Monthly interest (%)[e]	0.80	Aug. price	13.11
		Sep. price	12.04
		Oct. price	13.55
		Nov. price	12.63
		Dec. price	13.93

[a] Monthly average harvest price equals weighted seasonal average price for Rappahannock River oysters for 1984–87 plus or minus a monthly adjustment based on the average deviation of each monthly price from the seasonal average price for 1981–87.
[b] Seed count and size estimates were obtained from planter interviews.
[c] Seed prices are a weighted average of prices for public grounds seed for 1984–87 (VMRC 1988).
[d] Transplant charges include harvesting the premature oysters, transporting them upriver, and planting them on the new site.
[e] The interest rate is a real risk-adjusted rate. The average one-year Treasury Bill rate (Board of Governors of the Federal Reserve System) for 1984–87 was used as the risk-free nominal interest rate. The inflation rate represented by the average annual change in the implicit price deflator for gross national product (U.S. Department of Commerce) for 1984–87 was subtracted and a 5% risk premium added to account for risk.

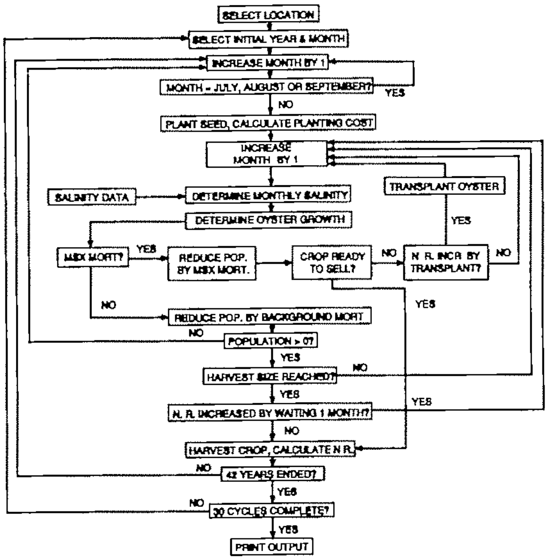

Figure 1. Oyster bioeconomic model

and the salinity-dependent disease MSX. The inverse relationship between mortality and oyster size derived by Askew (1975) was used to calculate background mortality.

A model of infection and mortality from MSX was constructed based on research summarized in Andrews as well as interviews with scientists at VIMS. Within the model, infection occurs only during May through October and when salinities are high enough to trigger infection. After MSX infection, a period of incubation is required before mortalities begin. Mortalities occur only from June through September and when salinities exceed a mortality threshold that is possibly higher than the level that triggers infection. Monthly mortalities average 20% of the month's beginning population. If MSX mortalities occur during the June–September period, surviving oysters are eliminated in the following June–September period assuming that salinities continue to equal or exceed the mortality threshold.

No growth occurs when the oyster has been infected and salinities are above the mortality threshold. If salinity falls below the mortality threshold but remains above ten ppt, no MSX-related mortality occurs and normal growth resumes. However, the oyster remains infected and mortalities resume when salinity rises above the mortality threshold. If salinity falls below ten ppt, the oyster eliminates all MSX infection (Sprague, Dunnington, and Drobeck).

Calculation of MSX mortality is a critical feature of the model. However, the exact salinities that trigger the infection and subsequent mortality from MSX are uncertain. The specific uncertainties are discussed in detail below.

If MSX mortality is observed and oysters have reached harvest size, oysters are harvested. If oysters are not market size, the possibility of transplanting oysters to lower salinity grounds is considered. Transplanting requires picking up the oysters using hand tongs or dredge, moving them by boat to an upriver location, and distributing them on the bottom. Whether transplanting is economical depends on the number of months that salinities remain high enough at the site to sustain MSX mortality. Oysters at a given location are transplanted only if doing so increases expected net returns for the entire distribution of salinities evaluated.

After oysters have reached market size of three inches, the planter may wish to wait another month before harvesting in order to obtain a higher price. Oysters are harvested only if net returns from harvesting in the present month exceed the discounted returns from waiting one month, recognizing the background mortality loss from waiting.

After the original crop has been harvested or destroyed by MSX, new seed are planted at the original site and the simulation continues for a forty-two-year period in order to capture a full historical pattern of salinities. A distribution of *NPV*'s for a given location is generated by repeating the entire forty-two-year cycle thirty times. By repeating the runs at multiple sites along the river, the model was used to calculate the distribution of *NPV*'s at grounds locations with different salinity patterns.

Multiple streamflow sequences, needed to predict monthly salinities, were synthetically generated using procedures suggested by Fiering and Jackson. The logarithm of streamflow in year i and month j ($LSF_{i,j}$) was generated as follows:

$$(4)\quad LSF_{i,j} = \overline{LSF}_j + (r_j s_j / s_{j-1})\, DEV_{i,j-1} + t_{i,j} s_j (1 - r_j^2)^{0.5},$$

where $\overline{LSF}_j$ and s_j are the mean and standard deviation of the logarithms of flow for month j; r_j is the correlation between the logarithms of flow for month j and month $j - 1$;[4] t is a random normal deviate with mean 0 and variance 1; and $DEV_{i,j-1}$ is the deviation between $LSF_{i,j-1}$ and $\overline{LSF}_{j-1}$. Means, standard deviations, and correlations of monthly flows were calculated from actual Rappahannock River data for 1910–86. Flow logarithms were converted to streamflows and used to predict salinity.

The simulation model was used to determine the potential contribution of different types of research information to the risk efficiency of oyster planting in the Rappahannock River. If the simulation results show that improved information would not alter the efficiency of planting, then research in these areas will have limited benefits and should not be pursued. However, choosing among the research areas that appear to have value will require information from outside the simulation model and is discussed later.

Model Validation

The structure of the simulation model was developed based on an intensive review of the biological literature and a series of extended interviews with professional oyster biologists at the Virginia Institute of Marine Science and private oyster planters. Key parameters from the growth and disease submodels were quantified using experimental data and expert interviews. These steps were taken to increase the model's face validity to oyster production experts (Law and Kelton).

Model results to be discussed later (table 3), show that for all but the nineteen-ppt mortality threshold, expected returns were negative at the mouth of the river and increased for locations further upriver where salinity levels and chances of MSX infection were lower. These results are consistent with the trend for planters to abandon high-salinity planting locations in the main portions of the Chesapeake Bay in favor of lower-salinity upriver locations after the onset of MSX in 1959 (Haven, Hargis, and Kendall). More detailed validation of model results is hampered by lack of complete data on the relationship between planting location, oyster growth, and oyster disease. Indeed, increased funding for oyster production and disease research is being emphasized because of data limitations and uncertainty about key model relationships.

Research Area 1: Faster Diagnosis of MSX

Planters perceive a trade-off between achievement of higher growth rates in higher salinity waters and the greater chance of losses to MSX disease in these waters. The risk involved in making this trade-off might be more manageable if faster diagnosis of the disease were possible. The planter then could plant in higher salinity waters for faster growth and salvage the crop for market or transplanting if salinities increase sufficiently to trigger the disease. MSX diagnosis currently requires extensive laboratory tests by shellfish pathologists (Dyckman). Research could focus on simpler, faster tests to detect the disease.

The simulation model was used to examine the effects on *NPV*'s of varying the length of time required to diagnose and harvest diseased market oysters from one-half to two months.[5] Table 2 reports the results for several river locations, using a mortality threshold salinity of eighteen ppt. Further discussion follows below on the mortality threshold; however, the results

[4] Month varies from 1 to 12; therefore, when j equals 1 (Jan.), $j - 1$ equals 12 (Dec.).

[5] Better methods of diagnosis might also be developed to determine if seed are infected by MSX. However, MSX infection is transmitted by an undetermined host, and infection and mortality are primarily determined by salinity at the grounds rather than presence of infection within the seed.

Table 2. Effects of Varying the Time Required to Harvest MSX-Infected Oysters on Net Present Values of Returns per 1,000 Bushels of Oysters

KM from River Mouth[a]	Months Required to Diagnose and Harvest 0.5	1.0	2.0
	Mean (Std. Dev.)		
	($)		
0.0	−4379	−6508	−9425
	(2639)	(2839)	(3304)
5.0	−4210	−6236	−8800
	(2715)	(2941)	(3422)
10.0	−3665	−5622	−8228
	(2931)	(3193)	(3550)
15.0	−1953	−3735	−5644
	(3333)	(3628)	(4079)
20.0	4310	4169	4169
	(3999)	(4045)	(4045)
25.0	11987	11987	11987
	(1416)	(1416)	(1416)
30.0	12727	12727	12727
	(758)	(758)	(758)
35.0	11921	11921	11921
	(955)	(955)	(955)
40.0	9990	9990	9990
	(986)	(986)	(986)
45.0	7532	7532	7532
	(687)	(687)	(687)
50.0	4873	4873	4873
	(995)	(995)	(995)

Note: Returns are stated as NPV's for a 42-year production cycle assuming that 1,000 bushels of seed are planted initially and each time oysters are harvested or lost to disease.

[a] Distances are kilometers from the mouth of the Rappahannock River.

reported in table 2 were insensitive to varying the threshold between fifteen and nineteen ppt. Mean net returns were increased in locations close to the river mouth where faster diagnosis permitted diseased oysters to be transplanted sooner. Mean returns increased little in upriver locations where transplanting was not economical. The most important result is that the maximum expected *NPV* occurred at the 30.0 km location, where no losses to MSX occurred. The variance at this location also was reduced compared with that at 25 km. Thus, no matter how fast the diagnosis, the economically prudent location was at 30 km, where MSX was avoided altogether. Increasing the risk of MSX disease loss in order to achieve higher growth rates was not an economically sound strategy. This simulation makes clear that planters would be best served by information telling them how to avoid MSX, which requires understanding of the relationship of the disease to salinity, or by development of an MSX-resistant seed.

Research Area 2: Relating Salinity to MSX Mortality

Management of oyster planting in the presence of MSX is made difficult by three sources of uncertainty: (*a*) the salinity that triggers MSX infection in the oyster; (*b*) the number of months required for MSX infection to incubate in the oyster before mortalities begin; and (*c*) the mortality threshold, that is, the salinity level at which oyster mortalities occur from MSX. Research trials in various sections of the river could be designed to monitor salinities and disease responses. The results could be used to determine which planting locations are most desirable from a risk-returns standpoint.

To simulate the value of improved information on these three factors, appropriate parameters within the disease loss component of the simulation model were varied for each of the simulation runs at each river location. First, the number of months of MSX incubation required before mortality occurs were varied with the infection trigger held constant at fifteen ppt and the mortality threshold set at eighteen ppt. Increasing the incubation period from one to three months caused relatively small increases in expected net returns in the downstream areas where salinities rose above the mortality threshold. For example, at 20 km the expected *NPV* was \$4,808 for a three-month incubation compared with \$3,781 for a one-month incubation. However, in upriver areas where salinity remained below the mortality threshold, the length of incubation had no effect on returns. Also, expected returns were still maximized by planting in these areas rather than further downstream.

Second, the salinity that triggers MSX infection was varied with the mortality threshold held constant at eighteen ppt and the incubation period set at two months. Increasing the salinity trigger had little effect on the location where expected returns were maximized. Increasing the trigger caused increases in returns in downstream areas where salinities were above the mortality threshold but did not affect returns in areas where salinities remained below the mortality threshold.

Third, the salinity threshold that induces mortality in infected oysters was varied between the values of fifteen and nineteen ppt. As noted, the threshold salinity may occur over a range from fifteen to twenty-five ppt (Andrews); however, the upper bound of nineteen ppt was chosen because salinity levels in the river seldom exceed twenty ppt at any location. For these simulations the trigger salinity for infection was held

Table 3. Effects of Variations in the Threshold Salinity for MSX Mortality on the Net Present Value of Oyster Enterprise Returns

KM from River Mouth[a]	Threshold Salinity for MSX Mortality (PPT) 15	16	17	18	19	Resistance
			Mean (Std. Dev.) ($)			
0.0	−10,881	−10,649	−10,315	−6,508	8,560	13,768
	(582)	(767)	(1,213)	(2,839)	(2,902)	(465)
5.0	−10,889	−10,655	−10,375	−6,236	10,016	13,752
	(566)	(777)	(1,202)	(2,941)	(2,371)	(471)
10.0	−10,853	−10,589	−10,305	−5,622	11,496	13,740
	(623)	(810)	(1,389)	(3,193)	(1,937)	(467)
15.0	−10,898	−10,621	−9,798	−3,735	13,120	13,677
	(642)	(783)	(1,645)	(3,628)	(1,069)	(440)
20.0	−10,827	−10,587	−8,387	4,169	13,512	13,512
	(693)	(1,011)	(2,019)	(4,045)	(513)	(513)
25.0	−11,003	−9,797	−4,967	11,987	13,347	13,347
	(707)	(1,620)	(3,156)	(1,416)	(543)	(543)
30.0	−9,977	−6,694	7,218	12,727	12,727	12,727
	(1,720)	(2,982)	(2,930)	(758)	(758)	(758)
35.0	−6,925	2,986	11,921	11,921	11,921	11,921
	(2,694)	(3,710)	(955)	(955)	(955)	(955)
40.0	3,524	9,990	9,990	9,990	9,990	9,990
	(3,357)	(986)	(986)	(986)	(986)	(986)
45.0	7,532	7,532	7,532	7,532	7,532	7,532
	(687)	(687)	(687)	(687)	(687)	(687)
50.0	4,873	4,873	4,873	4,873	4,873	4,873
	(995)	(995)	(995)	(995)	(995)	(995)

Note: Net present values refer to an enterprise in which 1,000 bushels of seed are planted initially and each time oysters are harvested.
[a] Distances are kilometers from the mouth of the Rappahannock River.

constant at fifteen ppt and the required incubation period was maintained at two months. Table 3 shows that for each threshold salinity, the mean *NPV* increased with distance from the river mouth until a maximum was reached; moving further from the river mouth reduced salinity levels and reduced the chances of MSX infection. After net returns reached a maximum, further movements upriver reduced returns because lower salinity caused oysters to grow more slowly, increased interest costs for the seed investment, and reduced yield by increasing total background mortality.

As the threshold salinity for MSX mortality was increased from fifteen to nineteen ppt, the maximum expected *NPV* increased substantially and occurred closer to the river mouth. With a fifteen-ppt salinity threshold, the risk-efficient distance was 45 km, with an expected *NPV* of $7,532 and a standard deviation of $687. With a nineteen-ppt salinity threshold, the risk-efficient location was 20 km with an expected *NPV* of $13,512 and a standard deviation of $513. Thus, if research found that the salinity threshold was nineteen ppt, planters could choose a location where expected returns are two to three times higher compared with upriver locations with variance essentially unchanged. However, research may find that the threshold is as low as fifteen ppt. The implications of this possibility for research priority setting are considered below. In any case, the simulations clearly indicate that only the salinity threshold for mortality is an important determinant of economic return.

Research Area 3: Development of MSX-Resistant Seed

Research toward development of an MSX-resistant oyster has been underway for a number of years. In order to develop MSX-resistant seed, the host that spreads the MSX virus must be identified in order to replicate the disease in the laboratory. Then breeding or immunization strategies to induce resistance can be evaluated (Schmidt).

The last column in table 3 reports the returns from planting MSX-resistant seed. These results were simulated by setting the MSX mortality threshold at a higher salinity level than was ever observed in the river. While MSX resistance will permit positive returns to be earned at all locations in the river, the number of locations where

MSX resistance increases the mean and reduces the variability of *NPV*'s diminishes with higher threshold mortalities. For example, at nineteen ppt the payoff for MSX resistance in terms of increased expected *NPV* is $256 ($13,768 − $13,512). However, if the threshold salinity is fifteen ppt, the payoff to MSX resistance increases to $6,236 ($13,768 − $7,532). The implications of the interdependence between the threshold salinity for mortality and the payoff from MSX resistance are considered below.

Research Area 4: Lower Seed Costs

Research that lowers the per unit cost of oyster seed is an alternative to spending funds on disease research. Using a mechanical or suction dredge to harvest seed rather than the labor-intensive, hand-tonging method could lower seed costs by 80% (Shabman and Thunberg). However, the state's oyster management plan (VMRC 1986) repeats a long-held concern that dredging might result in damage to certain types of seed beds. Because mechanical oyster seed harvest occurs in many other areas, such as the Potomac River and in Maryland, the extent of this damage and the cost effectiveness of repairing it by shelling grounds after harvest could be evaluated by research.

Another possibility would be development of low-cost hatchery technology (Kennedy and Breisch). Seed hatchery technology for the bay area has been under development for a number of years in both Maryland and Virginia. Recent prices for hatchery seed have averaged $3.50 per 1,000 seed (Webster and Meritt), while costs of James River seed have averaged over $5.00 per 1,000 seed. However, hatchery seed is not yet economically viable because of its smaller size and lower survival rate.

The effects of research that lowers seed costs are evaluated by determining the reduction in seed costs required to match the increase in net returns resulting from the availability of an MSX-resistant seed. The model was rerun to determine the seed price reduction needed to make the expected *NPV* without resistance equal to $13,768, the expected *NPV* obtained with MSX resistance at the river mouth. As discussed previously, the return to MSX resistance depends on the salinity threshold that causes MSX mortality; therefore, the necessary seed price reduction also varies by mortality threshold. The necessary reductions by threshold are: fifteen ppt, $1.12 per bushel; sixteen ppt, $0.66 per bushel; seventeen ppt, $0.33 per bushel; eighteen ppt, $0.18 per bushel; and nineteen ppt, $0.06 per bushel. These reductions vary from 2% to 37% of the $3.06-per-bushel base price. Thus, relatively small percentage reductions in seed price are likely to match the benefits to planters from an MSX-resistant seed.[6] These percentage reductions would be affected by changes in the ratio of market prices to seed prices. A decline in market prices relative to seed prices would lower the required reductions and make seed research more advantageous relative to development of MSX-resistant seed.

Setting Research Priorities

The simulation results eliminated some potential research priorities, including faster diagnosis of the disease, better knowledge of the salinity that triggers infection, and better knowledge of the time required for infection to incubate in the oyster before mortality. The simulation results support further consideration of seed harvest technology, seed hatchery technology, MSX-resistant seed, and the salinity threshold that causes MSX mortality. In order to set priorities among these possibilities, factors outside the simulation model must be considered.

Following Atkinson and Bobis, assuming the research funds administrator is risk neutral, the ranking can be based on the ratio of the expected present value of benefits and costs (B/C). The expected benefits of research depend on the joint probability that (*a*) the research will be successful, and (*b*) its results applied. Expected research benefits are calculated by multiplying this joint probability times the increase in the economic returns from the production process being studied if the research is successful and its results are applied. Research costs are the budget expenditures necessary to pursue research (Atkinson and Bobis). Simulation of the production process illustrates the economic benefits of research information if the research achieves its objectives, is adopted by producers, and is applied in a timely fashion. Clearly, the research administrator's expectations for the present value of benefits will depend not only upon the simulation results but also upon his subjective estimate of the probability for timely

[6] The possibility that increasing or decreasing the interest rate might significantly increase the advantage of MSX-resistant seed was evaluated. However, the required reductions in seed price needed to match the benefits from MSX resistance were insensitive to variations in the interest rate.

success and adoption of the research. The research administrator must also form a subjective estimate of research costs. Thus, the B/C is affected by four additional aspects of oyster research not addressed by the simulation model: the probability of research success, the probability and rate of adoption, the timing of benefits, and annual research expenditures.

Seed Harvest Technology Research

The research objective is development of mechanical seed harvest techniques (in lieu of hand-tong harvest) that lower per unit seed production costs without harming the long-term productivity of the public seed-growing areas, particularly in the James River. Evaluation of alternative mechanical harvest techniques combined with shelling to repair any damage done to the seed-growing bottoms could reduce seed costs in two ways. First, mechanical harvest would lower the cost per bushel of seed harvest. Second, replacing clean shell on harvested beds would promote more abundant setting of seed oysters on the beds. Because these techniques are used in Maryland, in the Potomac River, and on private seed grounds, the probability of research success for this project is high and the total cost will be low.

The probability of adoption of the new technology is more problematic. Historically, seed harvesters who use traditional hand-tong technology have resisted mechanical harvesting. However, given the declining number of hand tongers, this resistance should erode over time (Santopietro). On balance, this research area should have the highest B/C ratio due, in particular, to the high simulated benefits, the high probability of immediate success, the prospects for adoption, and the low cost.

MSX Threshold Research

The research objective would be to determine the threshold salinity that results in MSX mortality. The research would require an experiment that plants seed oysters at several locations over a period of years, monitors salinity, MSX disease incidence, and mortality, and then analyzes the data to isolate the relationships of interest. Although salinity is stochastic, table 3 makes clear that knowledge of the MSX mortality threshold would affect the choice of planting location. The benefits from successful research on this topic are uncertain and depend upon the research results. If the mortality threshold is low, then the realized payoff from this research would be low, although such results would provide justification for continuing the development of MSX-resistant seed. If the threshold is high, the payoff from this research will be high. The expected costs for such research to support the scientific personnel and equipment required for monitoring several locations for an extended time would be high. However, the probability of success would be high since the research procedure is a standard experimental design to better quantify a relationship about which much is already known.

If the salinity relationship is more precisely quantified, adoption of the information for planting decisions will require education of the planters about the results of the research. The B/C ratio for this project likely would be lower than for seed harvest technology research because of its higher cost and the uncertainty about the benefits. However, the B/C ratio likely would be higher than for hatchery technology and MSX research (discussed below) because of a high probability for research success.

Seed Hatchery Research

The objective of seed hatchery research is to provide seed at lower cost and with equal or better survival and growth potential than is currently available from natural seed-growing areas. Hatchery technology offers the potential to use breeding techniques to control seed size, shape, disease resistance, and other growth characteristics to produce a qualitatively better seed than is available from public bottoms (Austin, Dupuy, and Haven). Hatchery feasibility research has been conducted in the Chesapeake Bay area for several years (Greer), and as yet hatchery seed is not cost competitive with seed produced from public seed grounds even though hatcheries are already used in other areas such as the Pacific Northwest (Kennedy and Breisch). Thus, the probability of near-term success for economical hatchery production is unclear. Furthermore, the nature of the research makes hatchery technology studies more expensive than seed harvest research. In particular, hatchery research would involve genetic and environmental techniques to increase larval survival rates (Kennedy and Breisch), high-cost efforts because of their intensive use of scientific person-

nel and facilities. As a result, the expected cost of hatchery research is likely to be high. The probability of adoption given research success is likely to be high. Overall, the B/C ratio for hatchery research is likely to be lower than for public seed research primarily because of the high cost of hatchery research and lower probability of research success.

MSX Resistance Research

MSX research has the objective of developing an MSX-resistant seed that would ideally be no more costly than nonresistant seed. However, planters might also be willing to pay a higher price for the MSX-resistant seed if the higher prices were more than offset by economic gains from reduced MSX mortalities. The benefits of MSX resistance research depend upon the salinity threshold that induces mortality. If the mortality threshold is high, the benefits from MSX resistance will be low. The probability of immediate research success for this project is low. MSX research has been conducted almost since the disease was first diagnosed in Virginia waters in 1959, and researchers still cannot replicate the disease in the laboratory. Therefore, expected costs of this research are high. Although the probability of successful development is low, if developed the probability of adoption of MSX-resistant seed is high. The B/C ratio for MSX resistance research is probably the lowest of the four project areas primarily because of the low probability of success. However, the B/C ratio would be increased if the salinity threshold were low and only limited grounds were available in areas where this threshold is not exceeded. In that case, MSX resistance could lead to removal of a grounds constraint and increased plantings as well as increasing the returns per acre.

Conclusions

This study employed procedures to determine that research areas with the greatest potential to increase returns to oyster producers are seed harvest technology, the salinity threshold at which MSX mortality begins, seed hatchery technology, and development of MSX-resistant seed. Based on considerations not included in the simulation model, seed harvest technology and the MSX-mortality threshold are considered the most promising of the four research areas for increasing oyster industry profitability. Both of these areas would involve specific research projects applied to the goal of enhancing profitability of private oyster culture. The two least promising areas of research are development of hatchery technology and MSX resistance; they are oriented more toward basic research focused on increasing the scientific understanding of oyster biology and oyster disease. Given the importance placed upon basic research by oyster biologists (Sprague) and research administrators (Perkins), projects such as evaluation of mechanical seed harvest have received little funding support. However, funding such applied projects would not require abandoning basic research. Instead, applied projects should be part of a research portfolio because they are likely to produce valuable benefits for the oyster industry in a relatively short time.

The usefulness of simulation modeling for agricultural research evaluation is acknowledged (Kislev and Rabiner; Goodwin, Sanders, and Hollanda; Norton et al.; Pinstrup-Andersen and Franklin; Ruttan). While simulation models can show economic effects of research information, a comprehensive model requires subjective probability estimates of research costs and the potential for successful completion and adoption of research. Much of the peer reviewing of research proposals considers the probability that the research objectives can be achieved within the requested budget. Nonetheless, the peer review process could be structured to elicit more information on the research's probability of success, probability of adoption, and probability of obtaining different levels of benefits. Simulation models can help determine types of probability information needed to set research priorities.

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Optimal Scheduling in Shrimp Mariculture: A Stochastic Growing Inventory Problem

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Appropriate management tools are required for the successful introduction of advanced intensive technology in shrimp mariculture. This paper presents a stochastic dynamic decision model for evaluating the potential of the round pond technology practiced at the Oceanic Institute in Hawaii. The model provides the optimal stocking and harvesting schedules for a shrimp pond using a set of intra- and interseasonal decision rules. These rules are expressed as cutoff revenues when both prices and weights are considered random and as cutoff prices and cutoff weights when only prices or weights are considered random. The pond is not harvested if the current realized revenue is less than the cutoff revenue. The model simulates optimal scheduling using a set of 1986 shrimp prices for the case of random prices. Net profits are approximately doubled using the optimal schedules compared to conventional fixed scheduling schemes. The model also evaluates the economics of controlled environment.

Key words: decision model, growing inventory, optimal scheduling, shrimp.

Shrimp aquaculture is a potential industry in the Pacific, but is not profitable with current prices and existing technology. New management strategies and technologies are essential for improving the profitability and competitive potential of the Pacific region in the world shrimp market.

Shrimp ranks second in volume, behind tuna, and first in value of total U.S. seafood consumption. The U.S. is the world leader in shrimp consumption, consuming over 600 million pounds annually. Japan is a close second. Tropical, or penaeid, species represent the major part of the shrimp market in the U.S. and Japan. Worldwide shrimp culture represents approximately 15% of the four billion pounds of shrimp placed on world markets. Farm-raised shrimp could constitute about 25% of the world market by 1990 (U.S. Dep. of Commerce), and about 35% of the tropical shrimp market (Aquaculture Digest).

This paper presents a model for efficient management of shrimp farms in the Pacific region with an emphasis on the optimal market age of cultured marine shrimp. This quantitative management tool, which determines the optimal market age in a dynamic uncertain environment, will contribute to a successful shrimp culture industry.

Pacific shrimp farms have the capacity to produce several crops a year, and this is important to maximize profit. Determining the correct time to harvest is a major problem. Higher potential prices for larger shrimp are weighed against selling smaller shrimp and starting a new crop. There are also seasonal variations in shrimp prices and growth rates.

Risk is involved because the decision concerns future activities and the decision process is implemented at specified future time intervals. Two elements of risk are analyzed in this paper: the biological growth process, because of the limited practical experience, and the uncontrollable market price faced by the Pacific pro-

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ducers, who are a small part of the world market. This complicates the identification of the optimal market age. Other types of risk such as damaging algae blooms or viral attacks are not considered here. The basic management unit in this analysis is a pond. This implies that risk is considered to be identical across all ponds in a farm.

Conceptual Framework

This section introduces the conceptual framework for determining the optimal harvesting policy for a single pond. This is an important operating problem for tropical and subtropical shrimp farms. The focus of attention is on the continuous operation of a single pond. Thus, the shrimp producer operates within a given capacity and his decision is short-run in nature. Nevertheless, his production and pond management decisions are carried over time. Time enters at two levels: (*a*) the age of the growing crop of shrimp, and (*b*) the calendar date of harvesting.

In this context, the case of cultured shrimp is an extension of the sequential decision model of growing inventory developed and applied to a broiler producing firm (Hochman and Lee, Rausser and Hochman). There is a close resemblance between these two growing crops. At each age the size distribution and quality of the animals are close to homogenous in the sense that variation in the distribution is very small under normal operation. Therefore, for a given age, the grower faces a dichotomous decision: whether to sell the crop and enter the new period with a new crop, or to keep the old crop and defer the sale decision to the next period.

The differences between the two crops require extension of the framework beyond the broiler model. While the broiler growth processes are well known, the shrimp aquaculture technology is in its infancy. Hence, the proportion of factors that are uncontrolled is considerably higher than with broilers. For example, the air and water temperatures, waste products, and other water quality determinants are hard to control and subject to random variation. Another feature which characterizes shrimp production is the positive relationship between the price and the size which implies a significant differentiation of the product. These distinctions are absent in broiler operations. However, for both crops, risk is introduced through uncertain market prices. Thus, in the case of the shrimp operation, risk is introduced both through uncertain weights and uncertain market prices.

The only operational management model for shrimp culture was developed by Karp, Sadeh, and Griffin. They used dynamic programming to determine the optimal stocking and harvest rates of *P. stylirostris* in the Southwest, where production is continuous for only eight months in a year. However, their dynamic program was exceedingly large with 3,501 different states and cumbersome to apply in a practical setting. In addition, their model placed a heavy emphasis on environmental uncertainty, which is great in the southern United States, and assumed prices were fixed. In contrast, the conditions in the tropics allow year-round growing of shrimps. In that case, price uncertainty is as important as environmental uncertainty.

The state of the system in shrimp culture is defined by: (*a*) the age of the crop as it relates to weight (the growth process) and by extension to the price of shrimp through the price/size relationship; and (*b*) the calendar date of the year through the effect of seasonality on the physical growth processes as well as on the shrimp prices. Thus, the gross revenue per animal received from selling a given crop of age x weeks at a calendar week t can be expressed as[1]

$$(1) \qquad R_n(x, t) = W_n(x, t)P_n(x, t)$$

for $x = x_0, x_0 + 1, \ldots, X$ and $t = 1, 2, 3, \ldots,$ 52 weeks, where $W_n(x, t)$ is the current weight and $P_n(x, t)$ is the current price.

The age of the crop determines both the weight (or size) and the price. There is also a seasonality effect (i.e., the chronological date, t, of the year) on revenue through environmental impacts (e.g., temperature) on the growth of the animal and/or through the seasonality of demand (e.g., Christmas time).

It is assumed that, although the shrimp producer knows the current revenue, next week's revenue includes stochastic (random) elements that make its cash value uncertain. Therefore, without loss of generality, revenue is assumed to be a random variable with a known distribution $h(R)$ that may be univariate if either weight or price are random, or bivariate if both price and weight are random. Thus, the value R_n is the current sales revenue from the density $h(R)$.

[1] The present model is formulated on a per animal basis and mortality is introduced explicitly in the profit calculation. Mortality is assumed to be density-independent due to lack of information. However, this can be modified easily when additional information becomes available.

The case of random prices is characterized by a price-taking firm marketing either to local or export markets. A firm marketing most of its product to a stable local market may consider the price-quantity relation as deterministic. Stochastic variations in weight may be caused by fluctuations of temperatures as well as other environmental factors. Also, when new technologies are introduced, randomness in the weight figures should be considered.

The deterministic cost function is defined as $C(x, t)$ which has fixed costs per crop (mainly the post-larva purchase costs) and variable costs which depend on age such as feed, labor, and energy costs. The immediate net return can then be calculated as $R_n(x, t) - C(x, t)$. Thus, the problem of continuous optimal shrimp production and harvesting can be formalized as a Markovian dynamic programming model.

Let f_n represent the maximum expected return for the last n periods (weeks). If the producer begins at stage n with a crop at age x and calendar date, t, then,

(2)

$$f_n(x, t) = \max_{R^*(x,t)} \left\{ \int_0^{\infty} M(R_n(x, t), x, t)h(R)_t dR_t \right\}.$$

The decision rule is to sell the crop or to keep it. Thus, the optimal policy has the form,

$$(3) \qquad M(R_n(x, t), x, t) = \begin{cases} f_{n-1}(x + 1, t + 1), & \text{if } R_n < R^*(x, t) \\ R_n(x, t) - C(x, t) + f_{n-1}(x_0, t + 1) & \text{if } R_n \geq R^*(x, t), \end{cases}$$

for $x = x_0, x_0 + 1, \ldots, X - 1$; $t = 1, 2, \ldots,$ 52 weeks.

The decision is such that for each age, x, and calendar week, t, if the current realized gross revenue, $R_n(x, t)$, is less than $R^*(x, t)$, keep the crop and delay the decision to sell for another week, otherwise sell the crop if $R_n(x, t) \geq R^*(x, t)$. Therefore, $M(R_n(x, t), x, t)$ is a dichotomous return function that can take one of the two values, according to whether the decision is to keep or to sell the crop. By Bellman's principle of optimality, for all values of $R_n(x, t)$ that fall within the domain of the decision to keep, $M(R_n(x, t), x, t)$ will take the value of maximum expected returns for the last $(n - 1)$ periods, i.e., $f_{n-1}(x + 1, t + 1)$ and for the decision within the domain of the decision to sell, $M(R_n(x, t), x, t)$ will consist of the realized immediate net returns, i.e., $R_n(x, t) - C(x, t)$ plus the maximum expected returns, in the case of a decision to sell, for the last $(n - 1)$ periods, i.e., $f_{n-1}(x_0, t + 1)$.

The optimal policies that result consist of fifty-two vectors of cutoff revenues, $R^*(x, t)$. Each one of the vectors represents the solution for a given week, t, in the year. The fifty-two cutoff vectors depict the impact of the calendar time, while any given vector of cutoff revenues is related to the age of the growing inventory, i.e., for each age a critical value of revenue is defined such that any current realized revenue that is below it will result in a decision to keep the crop and wait for next week, otherwise the decision is to sell the crop.

The Homogenous (Calendar Independent) Case

In the absence of seasonality, if both the environmental and biotechnological conditions that affect the weight distribution of the animal and the market conditions that determine the price distribution are the same and identical in each and every calendar week, the vectors of cutoff revenues will be identical for each of the fifty-two weeks of the year. In this case the calendar week, t, is omitted from equation (1) to yield,

$$(4) \qquad R_n(x) = W_n(x)P_n(x)$$

for $x = x_0, x_0 + 1, \ldots, X$, where $W_n(x)$ and $P_n(x)$ are the corresponding current weight and price.

Note that the calendar date, t, is not in the equation because it will not affect the current value in the homogenous case. Also, the revenue distribution, $h(R)$ will remain the same for all weeks of the year.

In this case the dichotomous decision can be depicted by the following set of optimal decision rules for each corresponding age group:

$$(5) \quad V(x) = \max\left\{R(x) - C(x), \int_{R^*(x+1)}^{\infty} V(x + 1)h(R)dR - \pi\right\}$$

for $x = x_0, x_0 + 1, \ldots, X - 2, X - 1$, where $V(X) = \int_0^{\infty} R(X)h(R)dR - C(X)$ corresponds to the age X of termination at any current revenue; $R^*(x)$ is the cutoff revenue at age x; $C(x)$ is the cost of keeping the crop until age x; and π is the expected returns of one week as the system

operates for a long period of time [see discussion of equation (6c) below]. This set of equations (5) is best explained by their first-order conditions. The solution of the set of equations (5), which contains the optimal policy of harvesting the given shrimp pond, will define a unique vector of cutoff revenues, $R^*(x_0)$, $R^*(x_0 + 1), \ldots, R^*(X - 1)$ such that

$$(6)\quad R^*(x) - C(x) = M[R^*(x + 1), (x + 1)] - \pi + H_{x+1}\{M[R^*(x + 2), (x + 2)] - \pi\} + \ldots + H_{x+1}H_{x+2}\ldots H_{X-1}\{M[R^*(X) = 0, X] - \pi\},$$

where

$$(6a)\quad M[R^*(x), x] = \int_{R^*(x)}^{\infty} R(x)h(R)dR - c(x)$$

$$\text{given}\quad H_x = \int_0^{R^*(x)} h(R)dR$$

for $x = x_0, x_0 + 1, \ldots, X - 2, X - 1$,

$$(6b)\quad M[R^*(X) = 0, X] - \pi = V(X) - \pi$$

given $H_X = 0$, and

$$(6c)\quad \pi = \frac{M[R^*(x_0), x_0] + H_{x_0}M[R^*(x_0 + 1), x_0 + 1] + \ldots + H_{x_0}H_{x_0+1}\ldots H_{X-1}M[R^*(X) = 0, X]}{(1 - H_{x_0}) + 2(1 - H_{x_0+1})H_{x_0} + 3(1 - H_{x_0+2})H_{x_0+1}H_{x_0} + \ldots + (X - x_0)H_{X-1}H_{X-2}\ldots H_{x_0+1}H_{x_0}}.$$

Equation (6) states that after deducting $C(x)$, the cutoff revenue at a given age, $R^*(x)$, is determined such that it equals the conditional net expected returns of the shrimp crop from age x to the termination age, X, of the specific shrimp pond. Thus, for example, the last term on the right-hand side (RHS) consists of the product of the probability of a crop at age x to reach the age of $(X - 1)$ times the net returns at the terminal age X. The term "net" [for the RHS of (6)] is used since the opportunity costs of deferring the harvest for one week, π, are deducted from the conditional expected return of each of the following weeks of operation.

In (6a), the conditional expected return at any given age, x, is defined over the domain of 'Sell,' while H_x is the conditional probability to delay harvest for another week of a crop that reaches age, x. Condition (6b) is a transversality condition stating that at the age X the shrimp producer will harvest and sell at any current revenue, i.e., $H_X = R^*(X) = 0$. In (6c) the numerator of π measures the expected return per crop up to age X and the denominator measures the expected life of the crop.

As in the general case [see eq. (1)], the distribution of revenue in the homogenous case [eq (4)] may depend on an univariate distribution o the price or the weight, or on a bivariate distri bution that depends on both:

$$(4a)\quad R_n(x) = W(x)P_n(x), \text{ or}$$

$$(4b)\quad R_n(x) = W_n(x)P(x).$$

Thus, in the case of (4a), only prices are randon and the growth relations are deterministic. Th optimal solution will define a unique vector o cutoff prices, for each age a $P^*(x)$, such that i the current price, $P_n(x)$, is lower than the cutof price, $P^*(x)$, the crop should be kept for anothe week; otherwise, the crop should be harveste and a new crop begun. The negative relation ships between the cutoff prices and the age o the stock have been proved by Hochman.

In the case of equation (4b), where the weigh is random and prices are given and fixed for eac age, the optimal policy will consist of a vecto of cutoff weights, $W^*(x)$, that replace the vecto of cutoff prices, $P^*(x)$. Thus, if the averag weight of the shrimp in the pond, $W_n(x)$, is large than or equal to $W^*(x)$, the current crop shoul be harvested and a new crop started; otherwise the grower should wait another week and checl to see if $W_n(x + 1) \geq$ or $< W^*(x + 1)$, and s on.

In (4), the general case of the homogenou model is when both weight and price are sto chastic. If the weights and prices are indepen dently distributed, the vector of cutoff revenue $R^*(x)$ has the same properties as those of th previous vectors $P^*(x)$ and $W^*(x)$.[2]

The decision process can be described a Markovian. In the homogenous case, it is an er godic Markov chain. Each strategy chosen b the shrimp producer determines simultaneousl the cutoff revenue $R^*(x)$, the transition proba bilities H_x and the immediate reward. Moreover because H_x has a one-to-one correspondence witl the cutoff revenue, at each age one and only on decision variable determines the strategy taken H_x defines the transition probability matrix a follows:

[2] A formal proof of the random price case can be found in Hocl man. The same rationale can be extended to the random weight an the more general random revenue cases.

(7)
$$T = \begin{bmatrix} 1-H_{x_0} & H_{x_0} & 0 & .. & 0 \\ 1-H_{x_0+1} & 0 & H_{x_0+1} & .. & 0 \\ \vdots & \vdots & \vdots & .. & \vdots \\ 1-H_{X-1} & 0 & 0 & .. & H_{X-1} \\ 1 & 0 & 0 & .. & 0 \end{bmatrix}.$$

T is a complete ergodic Markov chain, with steady state probabilities, q_x, to be at a given age group such that,

(8)
$$\pi = \sum_{x=x_0}^{X} M[R^*(x), x]q_x, \text{ and}$$
$$\sum_{x=x_0}^{X} q_x = 1.$$

The General Model-Interseasonal Effects

The solution for the general model described in equation (2) consists of fifty-two vectors of cutoff revenues, $R^*(x, t)$. The Markov chains are no longer completely ergodic, so the steady-state probabilities depend on the initial state. In this case, randomness of prices and weights may also be introduced separately and simultaneously. The optimal policies will take into account the new dilemma the shrimp producer faces, i.e., to sell the crop and enter a new season with a young stock, or to keep the old crop and enter the new season with an old stock. Each of the weekly vectors can be interpreted as in the homogenous case. The negative relations between the cutoff revenues and the age of stock still hold. Moreover, as an approximation, one may derive the steady-state probability and the corresponding π for each of the weekly vectors assuming the conditions of this week will hold for the rest of the period.

An Operational Discrete Model

The basic functional equation (2) can be rewritten in a form manageable for computational purposes, where the continuous distribution is approximated by a histogram of J-equal probability rectangles to yield

(9)
$$g_n(x, t) = \max \begin{bmatrix} S: R_j(x, t) - C(x) + E_R[g_{n-1}(x_0, t-1)] \\ K: E_R[g_{n-1}(x+1, t-1)] \end{bmatrix}$$

for $j = 1, 2, \ldots, J$; $x = x_0, x_0 + 1, \ldots, X - 1, X$, and

$$t = \left\{ \begin{array}{ll} 1, 2, \ldots, 13 & \text{(fall season)} \\ 14, 15, \ldots, 26 & \text{(winter season)} \\ 27, 28, \ldots, 39 & \text{(spring season)} \\ 40, 41, \ldots, 52 & \text{(summer season)} \end{array} \right\},$$
$$J = 20, X = 15,$$

where

$$E_R[g_{n-1}(x, t)] = \frac{1}{J} \sum_{j=1}^{J} g_{n-1}(x, t)$$

for $x = x_0 + 2, x_0 + 3, \ldots, X - 1$, and

$$E_R[g_n(X, t)] = \frac{1}{J} \sum_{j=1}^{J} R_j(X, t) - C(X) + E_R[g_{n-1}(x_0)].$$

Equation (9) serves as the basis for the search through all possible current states for the optimal policies. The efficiency of the algorithm is achieved by making use of the recursive characteristics of the solution following three nested loops: (*a*) At a given week for a given age of the crop, the search for the cutoff revenue is done by approximating the revenue distribution by twenty revenues of equal probability, i.e., .05 for each revenue.[3] The search starts from the highest revenue downward, stopping at the first revenue that results in a decision to keep the crop for another week. Obviously, for any revenue below it (above it) the decision is to keep (sell) the crop. (*b*) The search moves then to the next younger crop at this week and the solution of the relevant cutoff revenue is obtained through the first loop. The second loop continues until all possible ages are considered, and then the search moves to the third loop. (*c*) The preceding week is introduced and the first and second

[3] The respective distributions of prices and weights approximated by dividing the area under the distribution curve into a histogram of 20 equal probability rectangles. Thus, the values corresponding to $j = 1, 2, \ldots, 20$ in equation (12) for the case of random prices [or equation (11) for the case of random weights] are assigned in a monotonic increasing order such that the value corresponding to 1 (20) is the lowest (highest) value from the equal probabilities array of prices (or weights). For the case of random revenue, the 20 values of the array of equal probabilities revenues from the bivariate distribution is obtained from a discrete joint probability table, where the rows are the 20 prices and the columns are the 20 weights. Thus, each of the 400 values of revenue (equal to price times weight combination) has an equal probability of 1/400. The four hundred possible revenues are arranged in an ascending order according to their values, so that they can be used to generate the revenue index $j = 1, 2, \ldots, 20$ of the ascending values of equal probability of .05.

loops are repeated. The third loop continues until all the weeks in the year (52 weeks) are exhausted. Then the same process is followed during the preceding year through the three loops. Starting from the third year, the fifty-two vectors of cutoff revenues in the last two consecutive years are compared and the search process stops when the optimal policies are identical.

The same algorithm is used for both the random price and random weight cases, where the critical values are the cutoff prices and cutoff weights, respectively. The solution algorithm has been programmed in Pascal on an IBM personal computer.[4] Convergence generally requires a few minutes and three to six iterations. The solution consists of the simulations of invariant optimal policies for the fifty-two weeks of an annual production and marketing plan. An empirical example of the model's use is presented in the next section.

Optimal Scheduling of Production and Marketing in a Shrimp Producing Farm in Hawaii

Scarcity of land and high labor costs dictate intensive shrimp production in Hawaii. Early failures in Hawaiian shrimp production demonstrate the need for advanced technologies and management. This section demonstrates how the conceptual framework of the preceeding section can be used as a managerial analysis tool, with particular reference to the round pond technology at the Oceanic Institute in Hawaii.

The Oceanic Institute constructed an experimental intensive shrimp pond at Makapuu in 1985. The pond incorporates features from intensive systems from around the world. It is round in shape, 1 meter deep, slightly sloped to the center, 337 square meters in area, and has a large center sump/drain. The sides of the pond are cement block and the bottom is compacted dirt. A paddle wheel aerates and mixes the pond water in a circular pattern that causes organic wastes to accumulate in the center drain for disposal.

Seven production trials have been conducted since 1986. The Ecuadorian white shrimp, *Penaeus vannamei*, was selected for the trials because of excellent growth characteristics, disease resistance, and high market value. The trials were stocked with animals from 0.7 to 1.56 grams at densities ranging from 45 to 150 animals per square meter. Survival ranged from 78% to 98%, and feed conversion efficiency ranged from 2:1 to 3:1. The animals were harvested at sizes from 15.1 to 26.1 grams (Wyban, Sweeney, and Kanna). These trials provided biological growth estimation data for this study.

Estimated Growth Relationship

Several growth relationships (linear, quadratic, logistic, and log-reciprocal) were tried. The most plausible form was the log-reciprocal:

$$W = e^{\alpha_0 - \alpha_1(1/x)}, \tag{10}$$

i.e., $dW/dx = \alpha_1 W/x^2 > 0$ and $d^2W/dx^2 \geq$ or ≤ 0 with an inflection point at $x = \alpha_1/2$.

The following equation was estimated in order to take into account temperature and stocking density effects on the growth coefficient, α:

$$\ln W = 4.59 - \underset{(32.20)}{238.25(1/x)} + \underset{(4.42)}{18.53DT(1/x)} + \underset{(1.16)}{5.72DD1(1/x)} + \underset{(2.34)}{14.53DD2(1/x)}, R^2 = 0.96, \tag{11}$$

where W is the average weight of the animal in grams; x is the animal age in days; DT is a dummy variable that takes the value of 1 for temperature greater than or equal to 26° C and 0 otherwise; $DD1$ and $DD2$ are dummy variables for density effects representing stocking densities of 100 and 75 animals per square meter, respectively; and numbers in parentheses are t-statistics. When $DD1$ and $DD2$ are both set to zero, it represents stocking density of 150 animals per square meter.

This log-reciprocal equation implies an asymptotic weight level of 98 grams and allows for varying growth rates. The influence of temperature was significant as shown in equation (11), and was applied later in deriving the two seasonal semiannual growth periods. The estimated relationship also indicated that higher stocking density would depress growth. A plot of the actual growth versus the predicted growth at 100 animals per square meter (used in the following analysis) for the two seasonal growth periods is presented in figure 1. These estimated

[4] The algorithm and the computer program are available upon request from the authors.

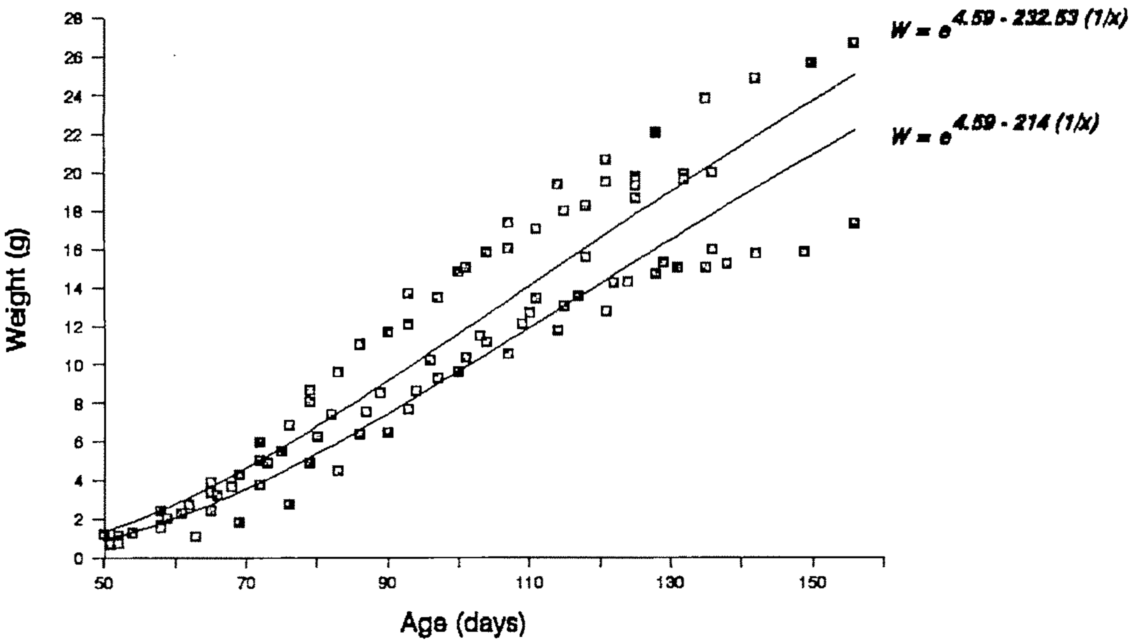

Figure 1. Shrimp growth functions

(12)

$$P = -0.008 + \underset{(37.05)}{0.161W} - \underset{(11.30)}{0.0008W^2} + \underset{(0.02)}{0.0006DS} + \underset{(6.02)}{0.200DF} + \underset{(2.85)}{0.0928DW}, \quad R^2 = 0.96, \quad \text{D-W} = 1.75,$$

growth relationships were used for predicting the weight-age relationship and estimating the random spread. The estimated standard deviation of 1.192 grams/animal was used to derive the univariate normal weight distribution, $h(W)$, and the bivariate normal revenue distribution, $h(R)$.[5]

Estimated Price-Size Relationship

The main market for Hawaiian shrimp producers is the U.S. mainland. Hawaiian producers are price takers in the mainland market. Weekly shrimp prices by size for the year 1985 were obtained from a weekly summary of Penaeid exvessel prices, headless, shell on, from National Marine Fisheries Service *Fishery Market News Reports* (U.S. Department of Commerce).

The size data were adjusted to weight data (there is one-to-one correspondence between size and weight), and were used in estimating the price-weight relationships, allowing for seasonal effects, as follows:

[5] The standard deviation (error) of the equation was chosen as a measure of risk rather than the total sampling variability which is composed of the equation error and the error in estimating the unknown parameters.

where P is price per pound; W is mean weight of size category in gm/animal; DS is a dummy variable for summer; DF is a dummy variable for fall; DW is a dummy for winter; D-W is the Durbin-Watson d-statistics, and numbers in parentheses are t-statistics.

No heteroskedasticity (higher price variance associated with higher weight) was found in this case. The estimated standard deviation, \$0.2625 per pound, was used to construct the price density function, $h(P)$, and the revenue function, $h(R)$.

Estimated Growout Operation Costs

The estimated costs figures are based on the OI round pond farm calculations. They were based on a hypothetical farm of twenty-four ponds, 0.2 hectare (0.5 acre) each with stocking density of 100 animals per square meter.

The feed intake assumed feeding rates based on wet weight of shrimp. Feed costs were calculated at \$0.00125 per gram of feed. Labor costs were calculated at \$203 per week per pond for regular sampling and feeding. Energy costs were calculated at \$56 per week per pond. Stocking

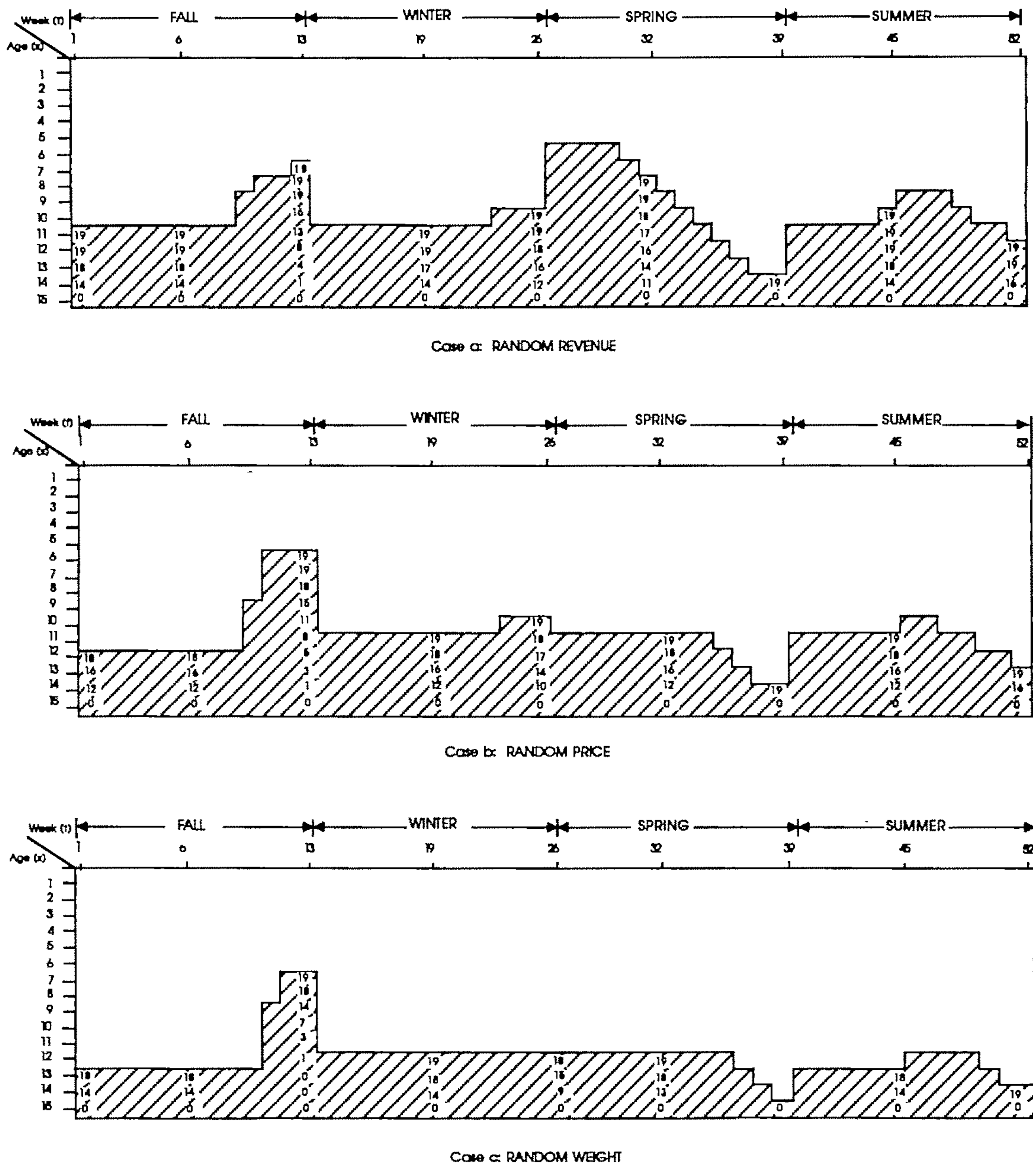

Figure 2. Inter- and intraseasonal optimal policy

costs were calculated at $3,000 per pond, for buying post larva and feeding it in a nursery for sixty-five days. The immediate net return at time t and age x can be defined as

$$P(x, t)W(x, t) - C(x, t),$$

where $C(x, t)$ is the sum of feed cost, labor cost, and energy cost up to age x plus the stocking cost.

Results: The Optimal Policies

The three graphs in figure 2, depict optimal policies for random revenues where both prices and weights are random, (2a), random prices, (2b) and random weights, (2c). The optimal policies are represented by an ordinal scale of cutoff values from 0 to 20 of equal probability for each week of the year and shrimp ages one to fifteen

weeks. The closer the number is to twenty, the higher the cutoff value and the higher the probability of postponing harvesting to the next week, a keep situation. For any given week the numbers will approach a sell situation (0), as the age of the shrimp increases to fifteen, the maximum allowable age. The cutoff value twenty is shown as blank in the graphs representing a keep decision always and the cutoff value zero represents a sell decision always.

Fall and summer have been assigned the growth relationship associated with temperatures above 26° C, while winter and spring have been assigned the growth relationship associated with temperatures below 26° C. Fall is the best season, with higher prices (about 40¢ per kg more on the average) and the best rates of growth owing to relatively higher temperatures. Next best is summer, with the same rate of growth (temperatures) as fall. The least favorable growth and market conditions occur in winter and spring.

The shapes of the frontiers in figure 2 are valuable in depicting interseasonal and intraseasonal trends in the optimal policies. Planned sales are higher in the fall, with the peak at the end of the fall to take full advantage of favorable prices at Christmas. The recommended optimal policy is to postpone harvesting during the last weeks of spring in order to use the favorable growth conditions during the summer. This tendency is strengthened by increased harvesting early in spring to increase capacity for younger crops by the end of spring and beginning of summer.

Table 1 depicts the invariant probabilities to sell for the corresponding optimal policies (i.e., corresponding cutoff values) in selected weeks for the three cases: random revenues (prices and weights), random prices, and random weights. The convergence to the invariant solutions was relatively fast (3–4 iterations), and the reported numerical values of the sell probabilities allow further insight into the detailed seasonal policies.

In table 2 the last week of fall (week 13) was selected to demonstrate the connection between the corresponding cutoff values and their corresponding probabilities on the histogram for a stock at a given age. In the case of random revenues, twenty rectangular histograms were calculated approximating the corresponding bivariate normal distribution for prices and weights for each age. For each of the twenty rectangles there is one value of cutoff revenue and its sell probabilitiy, i.e., the probability that the current revenue at this week for this age will be higher than the assigned cutoff revenue. For example, at the age of eight weeks a cutoff revenue of $109 per 1,000 animals corresponds to 0.05 probability of harvesting (i.e., 0.95 probability of waiting for the next week). Although ages seven, eight, and nine have the same probability to sell of 0.05, their cutoff revenues are different. In fact, the cutoff revenues are monotonically nondecreasing with age. Similarly, histograms of twenty rectangles for the normal price distribution at each age were approximated (the case of random price). At the age of ten weeks a 0.45 probability of selling (0.55 probability of waiting for the next week), corresponds to a cutoff price of $6.38 per kilogram. Because the average weight of a ten-week old animal in the last week of fall is 18.5 grams, the cutoff revenue, which corresponds to the $6.38 cutoff price, is $118 per 1,000 animals. The same can be traced for the third case of random weights with deterministic prices.

If the thirteenth week represents the rest of the year, i.e., the homogenous model, one may calculate the conditional expected net profit per week, π, as well as the expected length of the production cycles. However, given seasonal variations both in prices and weights, there are different policies over the various weeks. Even though the optimal policy patterns for the fifty-two weeks of the year can be calculated in advance, the long-run steady state probabilities and the resulting expected net profits cannot be calculated in a straightforward way as in the nonseasonal case. They depend on the vector of initial stocking dates.[6] The optimal solutions supply the producer with a priori, normative guidelines, but the actual realized policies may follow numerous trajectories. This motivated tracing the actual behavior of the OI shrimp farm during a specific year.

Simulation of the Shrimp Operation Using the 1986 Prices

The case of random prices with deterministic growth relationships was used to trace the behavior of the hypothetical shrimp farm facing the actual prices reported in the National Marine Service market news reports of 1986 (U.S. Department of Commerce). Table 3 shows the sequence of optimal actions assuming the starting date is the first week of fall. For example, at

[6] The Markov chain is not a complete ergodic one, but has periodic cycles.

Table 1. Probabilities to Sell for Selected Weeks of the Optimal Policies

Age (x)	Week (t) 1	6	13	19	26	32	39	45	52
			Case a: Random Revenues						
1–5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.05	0.00	0.00	0.05	0.00	0.00	0.00
9	0.00	0.00	0.05	0.00	0.00	0.05	0.00	0.00	0.00
10	0.00	0.00	0.20	0.00	0.05	0.10	0.00	0.05	0.00
11	0.05	0.05	0.35	0.05	0.05	0.15	0.00	0.05	0.00
12	0.05	0.05	0.60	0.05	0.10	0.20	0.00	0.05	0.05
13	0.10	0.10	0.80	0.15	0.20	0.30	0.00	0.10	0.05
14	0.30	0.30	0.95	0.30	0.40	0.45	0.05	0.30	0.20
15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Converged in 3 iterations.									
			Case b: Random Price						
1–5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.45	0.00	0.05	0.00	0.00	0.05	0.00
11	0.00	0.00	0.60	0.05	0.10	0.05	0.00	0.05	0.00
12	0.10	0.00	0.75	0.10	0.15	0.10	0.00	0.10	0.00
13	0.20	0.20	0.85	0.20	0.30	0.20	0.00	0.20	0.05
14	0.40	0.40	0.95	0.40	0.50	0.40	0.05	0.40	0.20
15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Converged in 3 iterations.									
			Case c: Random Weight						
1–5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.85	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.95	0.05	0.10	0.05	0.00	0.00	0.00
13	0.10	0.10	1.00	0.10	0.25	0.10	0.00	0.10	0.00
14	0.30	0.30	1.00	0.30	0.55	0.35	0.00	0.30	0.05
15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Converged in 4 iterations.									

the beginning of week ten, in the fall, the age of the shrimp is nine weeks with an average weight of 16.80 grams. The optimal policies derived in the previous section show a cutoff price of \$6.60 per kilogram. Comparing this number with the actual shrimp price (of \$8.89/kg) during the same period in the year, the decision is to sell the crop since it is more than the cutoff price. If the current market price is less than the cutoff price, a keep decision is recommended. In this case, a keep decision is recommended for all shrimp ages of less than nine weeks old. In other cases, a keep decision can result from a comparison of current market price and cutoff price. In the present case, the pond will be rested for two weeks (weeks 10 and 11) for cleaning. A new stock will then be introduced and the keep-sell decision will be determined as discussed above for another cycle. This tracing is done for one full year, as shown in table 3. This tracing produces 4.00 crops (in a year) with an average harvesting weight of 19.60 grams. The annual net profit is estimated to be \$203,269 for the hypothetical farm with twenty-four round ponds, 0.2-hectare each.

Table 4 summarizes the results of tracing four different cases according to starting dates at the first weeks of each of the four seasons. The operation that starts at the first week of summer yields the highest net profits, \$328,982 per year

Table 2. Probabilities to Sell and the Corresponding Cut-Off Revenues, Prices, and Weights for the Thirteenth Week

	Case a: Random Revenue		Case b: Random Price				Case c: Random Weight			
Age (x)	Prob. to Sell	Cut-off Revenue (per 1000 animals)	Prob. to Sell	Cut-off Price ($/kg)	Weight (g/animal)	Cut-off Revenue (per 1000 animals)	Prob. to Sell	Cut-off Weight (g/animal)	Price ($/kg)	Cut-off Revenue (per 1000 animals)
1–5	0.00	k	0.00	k	k	k	0.00	k	k	k
6	0.00	k	0.05	5.03	11.59	58	0.00	k	k	k
7	0.05	89	0.05	5.56	13.33	74	0.05	15.05	5.34	80
8	0.05	109	0.10	5.94	15.07	90	0.10	16.44	5.75	95
9	0.05	132	0.25	6.17	16.80	104	0.30	17.33	6.01	104
10	0.20	143	0.45	6.38	18.50	118	0.65	17.96	6.20	111
11	0.35	159	0.60	6.66	20.18	134	0.85	18.80	6.44	121
12	0.60	171	0.75	6.89	21.82	150	0.95	19.47	6.63	129
13	0.80	184	0.85	7.12	23.43	167	1.00	s	s	s
14	0.95	187	0.95	7.11	24.98	178	1.00	s	s	s
15	1.00	s	1.00	s	s	s	1.00	s	s	s

Note: k = keep; s = sell.

for the twenty-four ponds. It has on the average the highest marketing age (and weight) and receives therefore the highest price. The operation depends on the performance during all four seasons, and starting in the summer allows for the best management policies. Other starting dates may involve the loss of $69,000 to $149,000 as compared to operation starting in summer. However, such comparisons do not take into account labor constraints. There is a peak load problem in allocating the labor needed for harvesting if all ponds are started at the same date in summer.

Equally spaced harvests at age eleven weeks (4 crops per pound) is the other extreme. This allows ninety-six harvests per year, which is approximately two harvests per week. The strategy wil result in a loss of $3,750, operating in 1986 (see table 4, fixed scheduling). A hybrid strategy that starts in the summer and uses fixed scheduling, marketing at age thirteen weeks, would result in a net profit of $174,534. The

Table 3. Simulation of Optimal Policies for the Case of Random Price

Season	Beginning of Week	Age of Shrimp (Weeks)	Average Weight (gm)	Prob. to Sell	Cut-off Price ($/kg)	Current Price ($/kg)	Decision
Fall	1						stock
	.						
	.						
	10	9	16.80	0.05	6.60	8.89	sell
	11						rest
	12						stock
	.						
	.						
Winter	.						
	23	11	17.59	0.05	6.60	7.66	sell
	24						rest
	25						stock
Spring	.						
	.						
	.						
	39	14	22.18	0.05	7.68	10.36	sell
Summer	40						rest
	41						stock
	.						
	.						
Fall (next year)	1	12	21.82	0.10	7.88	10.27	sell

Table 4. Summary of Trace Results

Start Stocking in	Average Age of Shrimp (Weeks)	Average Weight (gm)	Cycles	Average Market Price ($/kg)	Net Profit ($)
	Case b: Random Prices				
Fall	11.50	19.60	4.00	9.30	203,269
Winter	10.80	18.74	4.18	8.55	179,592
Spring	11.40	20.23	4.14	9.50	259,720
Summer	11.50	20.26	4.14	9.63	328,982
	Fixed Scheduling				
Summer	13.00	22.05	3.47	9.00	174,534
Any season	11.00	18.88	4.00	7.98	−3,570

Table 5. Summary of Trace Results for Controlled Environment (Summer)

Start Stocking in	Average Age of Shrimp (Weeks)	Average Weight (gm)	Cycles	Average Market Price ($/kg)	Net Profit ($)
Fall	11.50	20.99	4.14	9.65	358,624
Winter	11.50	20.99	4.14	9.91	409,652
Spring	11.50	20.99	4.14	9.92	412,980
Summer	11.50	20.99	4.14	9.91	410,761

difference is the shadow price of a labor constraint.

This conceptual framework is helpful in answering another important question often asked by the farmer: How much should I invest in the new technology? As an example, the researchers at OI are interested in the possibility of creating a controlled environment at a constant high temperature of 28° C. To address this possibility the tracing procedure used in obtaining the results in table 4 was rerun assuming summer conditions (>26° C) during the whole year. The results are reported in table 5, indicating an increase in annual net profit of approximately $150,000 on the average in comparison to operation under the existing environmental constraints.[7] This provides the upper limit of the annualized investment cost.

Concluding Comments

A dynamic decision model has been developed to determine the optimal stocking and harvesting strategies of a shrimp-producing pond. The model captures both the dynamics of the decision process and the risk involved. Risk is represented by randomness in market prices and growth of shrimps. The model provides a set of optimal policies for each calendar week of a year and for each given age of the growing shrimps. This model was applied to analyze the economics of the round pond technology recently developed at the Oceanic Institute in Hawaii. By using the management tool developed here, a hypothetical operation can increase its profitability about twofold as compared to fixed scheduling schemes. This surplus profit can be used to invest in the control of environmental quality as well as to alleviate shrimp health problems which may arise as a result of using intensive technology such as the round pond. The model developed here can be adapted and applied to any shrimp farming technology.

The model is an important base for further work in a complete farm setting where hatchery capacity and labor availability can be constraining factors. This model can also be successfully adapted to other growing crops if they are homogenous and production is of an all-in–all-out nature.

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[7] Although the average harvest age of shrimp and thus the average weight and cycles are the same in table 5, the individual crops have different harvest ages and weights. It is coincidental that the averages are identical.

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Informational Efficiency of Markets for Stumpage

Courtland L. Washburn and Clark S. Binkley

This paper examines the weak-form informational efficiency of markets for pine sawtimber stumpage in the U.S. South. Analyses of annual and quarterly rates of price change generally indicate that stumpage markets are efficient. When viewed over monthly intervals, stumpage markets do not pass the tests for weak-form efficiency. This failure is attributed to friction in the market due to the time and cost involved in consumating timber sales. The results have implications for price-responsive timber harvest scheduling, for the application of asset pricing models to forestry investments, and for policies governing sales of timber from public lands.

Key words: informational efficiency, market model, stumpage markets.

Are markets for stumpage informationally efficient (Samuelson 1965, Fama 1970)? This question attends several of the most important problems in forest economics. Stumpage market efficiency is a maintained, yet untested, hypothesis in most econometric analyses of timber supply (e.g., Berck, Adams and Haynes). Recent applications of the capital asset pricing model to forestry investments (e.g., Thomson; Binkley and Washburn 1988a, b; Redmond and Cubbage) assume that stumpage markets are efficient. Conversely, several recent papers rely on predictable departures from equilibrium price levels—market inefficiency—to argue that timber owners can make economic gains by adopting marketing policies which exploit stochastic variations in stumpage prices (Norstrom, Brazee and Mendelsohn 1988b, Lohmander 1988).

This paper examines the informational efficiency of markets for sawtimber stumpage. We determine whether the current price of sawtimber stumpage incorporates all of the information obtainable by studying past departures from equilibrium rates of price change. This is known as a test of "weak-form" market efficiency (Fama 1970).

In the next section the theory of storage (Working 1948, 1949; Brennan; Telser) is used to derive a rational expectations equilibrium (Muth, Kohn, Scheinkman and Schechtman) for stumpage markets. In equilibrium, the current price of stumpage will equal its expected future price, less expected capital costs and storage expenses (e.g., land rental and protection from fire and pests) plus the expected value of its physical growth. If new information alters expectations, then stumpage flows in or out of storage until the equilibrium is restored. As long as the store of stumpage is never exhausted and can be freely expanded or contracted, stumpage prices will never depart from equilibrium levels. Maintenance of the rational expectations equilibrium ensures that stumpage markets are informationally efficient.

The usual tests for weak-form market efficiency are conducted on time series of differences between actual and equilibrium rates of stumpage price change. Efficient markets are expected to produce white-noise deviations. This implies that departures from equilibrium rates are serially independent. We calculate two measures of serial dependence. The first, more common measure, is an autocorrelation function comprised of serial correlation coefficients. But parametric tests of serial dependence can reject the market efficiency hypothesis either because markets are indeed inefficient or because of incorrect parameterization of the underlying stochastic process. To bolster the results, a non-

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parametric test based on the number of turning points in the series is also conducted. Both tests are modified to account for the way stumpage price data are averaged within reporting periods. The tests are described in the second section below.

The analysis is confined to sales of private southern pine timber. Private sales were studied because prices reported for stumpage sold on national forests and other public lands are bid prices that are likely to reflect expectations of future prices rather than current market values.[1] The analysis was restricted to southern pine timber because prices from private sales of the other commercially important species of sawtimber stumpage—softwoods in the western United States such as Douglas-fir and western hemlock—are not publicly available. Even with these limitations, many series of sawtimber stumpage prices are available for study. We work with eighteen series, reflecting monthly and quarterly as well as annual observations.

Markets for southern pine sawtimber stumpage pass the tests for weak-form efficiency when viewed on an annual or quarterly basis but not necessarily when monthly returns are considered. The paper's final section discusses the implications of these results for price-responsive harvest scheduling, for the estimation of forest asset pricing models, and for policies governing the sale of timber from public lands.

A Model of Informationally Efficient Stumpage Markets

The theory of storage (Working 1948, 1949; Brennan; Telser) provides our rational expectations model of stumpage market equilibrium. Storage theory was developed to explain the storage of agricultural commodities. The theory postulates that owners of a storable good will withhold it from the market if they anticipate a price increase greater than storage and capital costs. Similarly, they will remove the commodity from storage if its current price is higher than its expected future value. Aggregated over all commodity owners, this behavior produces a rational expectations equilibrium in the commodity market (Muth, Samuelson 1971, Kohn Scheinkman and Schechtman). As long as there is a positive amount of the commodity in storage, the equilibrium is characterized by the following relationship between current prices and expected values:

$$(1) \qquad P_t = E_t[(P_{t+1} - c_t) \exp(-r_t)],$$

where P_t and P_{t+1} are per-unit commodity prices at the beginning of periods t and $t + 1$ respectively, c_t is the cost of warehousing the marginal unit under storage during period t (for convenience it is assumed payable at the end of the period), and r_t is the capital cost of holding the commodity during period t (alternatively, r_t can be viewed as the rate of return required by investors to hold the commodity).[2] E_t is the expectations operator conditioned on information available at the beginning of period t.

To adapt storage theory to stumpage, we express holding costs as a proportion of stumpage price and incorporate into the equilibrium relation the physical growth of the marginal unit of the stumpage store:

$$(2) \qquad P_t = E_t[P_{t+1} \exp(g_t - c_t - r_t)],$$

where P_t and P_{t+1} are per-unit stumpage prices at the beginning of periods t and $t + 1$ respectively, g_t is the growth rate of the marginal unit of stumpage in storage, c_t is the cost of storing the marginal unit during period t (e.g., land rent and protection from fire and pests), and r_t is the capital cost of holding stumpage during period t. This rational expectations equilibrium will hold and stumpage markets will therefore be informationally efficient, as long as (*a*) the store of stumpage is not exhausted and (*b*) movement of stumpage in and out of storage is frictionless.

For this analysis, variation in the marginal rate of growth minus storage cost ($g_t - c_t$) is assumed negligible over the operational size range of the stumpage store. Although some researchers might argue against such an assumption (e.g. Brazee and Mendelsohn 1988a; Schworm, Hoaas and Hyde; Boyd and Hyde), it is justified here on several grounds. First, the operational size

[1] Purchasers of public stumpage are usually given several years to harvest their timber. Payment is not made, aside from a small deposit, until the timber is harvested. (Since 1986, the Forest Service has required payment for one-half of the timber by the midterm of the contract.) Thus, buyers of public stumpage will base their bid on the stumpage price they expect to prevail on the probable harvest date (which could be several years in the future) rather than on the current stumpage price. We thank an anonymous reviewer for making this point.

[2] In this formulation, the cost parameter c incorporates the "convenience yield" of storage (Kaldor). Convenience yield was proposed to account for "inverse carrying charges," the empirical observation that commodities are stored even when the costs of storage appear to outweigh the benefits. The flexibility that a stockpile of the commodity gives processors to respond to changes in product demand is the most commonly cited origin for the convenience yield

of the stumpage store is likely to vary over a rather narrow range. In the southeastern United States, for example, the net change in the stock of southern pine sawtimber stumpage was only 0.1%, 1.5%, 2.1%, 1.7%, and 0.4% in the years 1952, 1962, 1970, 1976, and 1984, respectively (USDA Forest Service). Second, any change in marginal growth rates that might occur as the stumpage store contracts or expands will be at least partially offset by a change in marginal storage costs. Consider, for example, a decrease in the size of the stumpage store. The marginal growth rate might increase if marginal harvests shift to younger stands of timber. However, younger timber occupies more land per unit of stumpage. Presuming that storage costs depend on land area, the costs per unit of stumpage would increase and thus offset the increase in marginal growth. Finally, a large part of the southern pine stumpage store is held by nonindustrial owners—individuals whose primary purpose of land ownership may not be timber production. (According to the USDA Forest Service, in 1984 nonindustrial owners held 63% of the southern softwood inventory.) For a variety of reasons, relatively high prices may be required to draw their timber into the market. Much of the timber they hold might be overmature in the sense that its rate of growth minus storage cost is smaller than at the margin of the stumpage store. Thus, as stumpage prices fluctuate about the "reservation" price of these nonindustrial owners, their timber is drawn in and out of the market without altering the value of $g_t - c_t$. As shown in the next section, the assumption that $g_t - c_t$ is constant allows the market efficiency tests to be conducted without data on growth rates and storage costs.

Expressing $g_t - c_t$ as a constant proportion (d) of per-unit stumpage price, the equilibrium condition becomes

$$(3) \qquad P_t = E_t[P_{t+1} \exp(d - r_t)].$$

Or, in terms of the rate of stumpage price change during period t (R_t):

$$(4) \qquad E_t[R_t - (r_t + d)] = 0.$$

If this rational expectations equilibrium is always satisfied, then stumpage markets are informationally efficient.

A Test of Informational Efficiency

Tests of the informational efficiency of markets seek to accept or reject an hypothesis that all relevant information is reflected in market prices, or, equivalently, that the current market price is the best estimate of any future discounted value. Before such tests can be conducted, the set of relevant information must be identified. Specifically, the expectations operator in relationships (3) and (4) must be conditioned on an identifiable information set.

Financial economists have traditionally used three categories of information to test market efficiency. Markets are weak-form efficient if they correctly incorporate information obtainable by studying historical prices, semistrong-form efficient if they reflect all publicly available information, and strong-form efficient if they account for both public and private information (Fama). The information categories are nested so that rejection of weak-form efficiency implies rejection of semistrong- and strong-form efficiency as well.

Empirical analyses of markets for financial assets have consistently supported weak-form efficiency, usually supported semistrong-form efficiency, but rarely supported strong-form efficiency (Malkiel). Efficiency tests of markets for real assets have been much less extensive. Analyses to date have generally supported the weak-form efficiency of markets for commercial and residential real estate (e.g., Gunterman and Smith), precious metals (e.g., Solt and Swanson), and agricultural commodities (e.g., Holthausen and Hughes).

Because this study tests the weak-form efficiency of stumpage markets, expectations are conditioned on an information set that consists of past departures from equilibrium rates of stumpage price change. The weak-form efficient condition can therefore be expressed as follows:

$$(5) \qquad E_t[R_t - r_t + d | R_{t-1} - r_{t-1} + d, R_{t-2} - r_{t-2} + d, \ldots] = 0.$$

Or, in *ex post* form,

$$(6) \qquad R_t - r_t + d = error_t,$$

where the expected value of $error_t = 0$ and $\mathrm{cov}(error_t, error_{t+j}) = 0$ for all j not equal to 0. In other words, departures of actual (R_t) from equilibrium ($r_t - d$) rates of stumpage price change are white-noise.

A testable implication of equation (6) is that departures from equilibrium rates of price change are serially independent. That is, past departures from equilibrium cannot be used to identify current departures. A finding of significant serial

dependence is cause to reject a joint hypothesis that stumpage markets are efficient and that equilibrium rates of stumpage price change conform to the specified model (Fama 1976).

That either market inefficiency or a misspecified model of equilibrium price change can cause the serial dependence test to reject the hypothesis is problematic. However, the market efficiency component of the hypothesis can be isolated to some extent by performing the tests with alternative models of equilibrium price change (Brenner). If the test results are robust with respect to the alternative models, then acceptance or rejection of the hypothesis can with greater confidence be attributed, respectively, to market efficiency or inefficiency.

In this analysis, the model of equilibrium stumpage price change depends on the model of capital cost (r_t). Two distinct capital cost models were adopted, each an alternative version of the Sharpe (1963) single-index market model. The market model postulates a linear relationship between equilibrium returns on individual assets and the value of a common market factor, or index, that affects the return on all assets. Alternative indices produce different models for the capital cost of holding stumpage. We selected two indices—returns to the stock market (m_t) and the rate of inflation (i_t):

(7) stock-based market model

$$r_t = a + bm_t + u_t, \text{ and}$$

(8) inflation-based market model

$$r_t = a + bi_t + u_t.$$

The models include a random disturbance term u that has an expected value of 0, is not serially correlated, and has zero covariance with the index.

The rate of return to the stock market is an obvious choice for the index. A stock-based market model is routinely used to explain variation in returns to financial assets. It produces essentially the same results as a capital asset pricing model (Sharpe 1964, Lintner) that uses stock market returns as a proxy for returns to the overall market portfolio.[3]

[3] The CAPM specifies the following relationship: $E_t r_t = rf_t + \beta(E_t M_t - rf_t)$, where rf_t is the risk-free rate of return during period t, and M_t is the rate of return on the overall market portfolio during period t. Although the theoretical bases of the market model and the CAPM are very different (Collins), a market model that uses a proxy for M_t (e.g., stock market returns) as the market index and the CAPM give similar results as long as the risk-free rate of interest is relatively constant over time. Brenner has shown that stock market efficiency tests are insensitive to the choice of one model over the other.

Although an inflation-based model is a less obvious choice than the stock-based formulation, the rate of inflation might be a reasonable index for forest assets. Conventional wisdom is that timber is a good inflation hedge. For example, Redmond and Cubbage (p. 335), suggest that inflationary expectations play a major role in determining the price of stumpage because it is held ". . . as a store of value for times of inflation. . . ." If the real risk-free rate of interest is constant and stumpage holders simply require a constant real risk premium, then the slope coefficient in the inflation-based model will be equal to one. Such a model of equilibrium stumpage price change has been used by Lohmander (1985) to test the efficiency of roundwood markets in Finland, Norway, and Sweden. It is also well known that stock market returns and inflation are inversely related (e.g., Fama and Schwert). Thus, stock-based and inflation-based models of capital cost differ and should provide a good indication of the robustness of serial dependence results to model specification.

The alternative models of equilibrium stumpage price change ($r_t - d$) produced by the two capital cost formulations can be estimated by ordinary least squares regression of realized rates of stumpage price change on realized stock returns or inflation:

(9) stock-based $R_t = \alpha + \beta m_t + \epsilon_t$, and

(10) inflation-based $R_t = \alpha + \beta i_t + \epsilon_t$,

where α is an estimate of the market model's constant term (a) minus the constant rate of stumpage growth less holding costs (d), and the error term ϵ includes the market model's random disturbance term (u).

The residual errors from regressions (9) and (10) represent departures from equilibrium rates of stumpage price change—the error term in equation (6). If the residual errors are serially independent, then stumpage markets pass the test of weak-form efficiency and weak-form information cannot be used to identify departures of stumpage prices from equilibrium levels.

To measure the serial dependence of the departures from equilibrium rates of price change we calculated the autocorrelation function. The autocorrelation function is a standard measure of serial dependence in market efficiency studies. It assumes, however, that the departures from equilibrium rates of price change are drawn from a normal distribution. If the rates are not normally distributed, then the correlation coeffi

cients, and particularly their standard errors, may be misleading. To assess the normality of the rates of change in our analysis, and thus the potential for serial correlation results to produce faulty conclusions, we calculated coefficients of skewness and kurtosis of each series and compared them with the values expected for a normal variate.

In the event that departures from equilibrium rates of stumpage price change are not distributed normally, we also conducted a nonparametric runs analysis for serial dependence called the turning point test (Kendall and Stuart). To conduct the test, the observed number of turning points—any peak or trough in the series—is compared to the number expected in a random series. A positive deviation from the expected number indicates negative serial dependence, and a negative deviation suggests positive dependence.

Interpretation of both serial dependence measures is complicated because stumpage prices are reported as averages of prices observed throughout a measurement interval (e.g, the average price during each calendar year) rather than values at a particular point in time (e.g., the price on 1 Jan. of each year). This averaging induces spurious positive dependence in the rate of price change between successive periods. Working (1960) determined that when rates of change are calculated from averages of random values at equally spaced intervals within a period (e.g., with annual average prices calculated from prices at the close of each month), the induced serial correlation at the first lag quickly approaches 0.25 as the number of intervals within the period increases. No correlation is induced at the second and all subsequent lags.

To the best of our knowledge, the number of turning points expected in an averaged, random series has not previously been quantified. Consequently, we conducted a Monte Carlo study to do so. The analysis is detailed in an appendix available from the authors upon request. In brief, random series were generated, period averages were calculated, and rates of change between successive periods were determined. Serial correlation tests on the rates of change confirmed Working's (1960) result of a correlation coefficient of 0.25 at the first lag and zero at subsequent lags. The number of turning points in the series averaged $(n - 2)0.604$, fewer than the $(n - 2)0.667$ turning points expected in a random series. Based on these findings, we chose as null hypotheses a coefficient of 0.25 at the first lag and zero at all subsequent lags for the serial correlation test, and $(n - 2)0.604$ turning points for the turning point test.[4]

Results

Historical price series were obtained for southern pine sawtimber stumpage sold from private land in the U.S. South. Timber Mart South (TMS) was the primary source. TMS has reported average statewide stumpage prices at monthly intervals since December of 1976. The monthly TMS prices were averaged to produce a comparable set of quarterly series. Other series of quarterly and annual prices were obtained from various state reports. Table 1 gives the reporting source, geographic coverage, measurement interval, and observation period of each series.

The monthly consumer price index (CPI) was used to measure inflation. To be consistent with the averaged stumpage price series, the inflation index was averaged over quarters and years to obtain quarterly and annual measures. Daily closing values of the Center for Research in Security Prices (CRSP) composite index of stocks on both the American and New York exchanges were averaged over months to obtain a monthly index of stock market value. The monthly values were then averaged to obtain quarterly and annual indices. Because the CRSP index dates back only to 1962, values of the Standard and Poor's 500 (S&P 500) index—adjusted by Ibbotson Associates to include reinvested dividends—at the close of each month were averaged to obtain quarterly and annual stock market series for use with stumpage price series that predate 1962.[5]

Rates of change in stumpage price, stock market value, and inflation were calculated as first differences of the natural logarithm of the series. Ordinary least squares regression was then used to estimate stock- and inflation-based models of equilibrium price change—relationships (9) and (10)—for each price series. Table 2 dis-

[4] The reported stumpage prices are not actually averages of prices at equally spaced intervals within periods. Rather, they are averages of sale prices observed at irregular intervals within periods, sometimes weighted by the volume of stumpage in the sale. This sort of averaging will induce the same degree of serial dependence as the averaging of prices at regular intervals within periods as long as the likelihood of a sale occurring and the expected sale volume are constant throughout each period.

[5] From 1962 through 1987, the correlation between quarterly CRSP and S&P 500 returns was 0.944. Thus, the use of different stock market indices should not materially affect the comparison of monthly with quarterly and annual results.

Table 1. Southern Pine Sawtimber Stumpage Price Series

Reporting Source	Geographic Location	Measurement Interval and Observation Period
Timber Mart South	Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia	Monthly, Oklahoma and Kentucky 1981–87, all others 1977–87
Louisiana Dept. of Agriculture, Office of Marketing (Annual averages reported in Ulrich)	Louisiana	Quarterly, 1955–87
Mississippi Forestry Commission	Mississippi	Quarterly, 1969–79
Arkansas Forestry Commission (1953–79), Timber Mart South (1980–87)	Arkansas	Annual, 1953–87
South Carolina Forestry Commission (FY 1950–FY 1976), Timber Mart South (FY 1977–FY 1987)	South Carolina	Annual, FY 1950–FY 1987

plays the coefficient estimates. To the extent that stock market returns measure returns to the overall market portfolio, the slope coefficients of the stock-based market model indicate the systematic or undiversifiable risk of holding stumpage. An asset with the same financial risk as the market as a whole has a coefficient equal to 1; the smaller the coefficient, the less the risk. The slope coefficients of the inflation-based model measure the ability of stumpage to hedge against realized inflation. A complete inflation hedge has a coefficient equal to 1.

The market model results are mixed. Monthly rates of change in the price of southern pine stumpage exhibited no significant relationship with inflation rates or stock market returns. On the other hand, the quarterly rates of change calculated from both TMS and Louisiana and Mississippi state reports are related directly, albeit weakly, to stock market returns. Whereas nine of the thirteen slope coefficients in the monthly stock-based model were negative, all of the quarterly TMS slope coefficients were positive. It appears that ownership of southern pine stumpage provides no hedge against inflation, and entails a rather small degree of systematic risk.

Autocorrelation functions of the regression residuals, which represent departures from equilibrium rates of stumpage price change, were estimated to twelve lags for the monthly, eight lags for the quarterly, and four lags for the annual price series. The results for the stock-based residuals are presented in table 3 and for the inflation-based residuals in table 4. Because period averages were used to calculate rates of price change, the null hypothesis of no serial dependence, and weak-form market efficiency, is a correlation coefficient of 0.25 at the first lag and 0 at all further lags.

The monthly departures from equilibrium rates

Table 2. Estimates of Alternative Models of the Equilibrium Rate of Southern Pine Sawtimber Stumpage Price Change

	Stock Market Model		Inflation Model	
Price Series	α	β	α	β
Monthly (Timber Mart South)				
Alabama	0.0046	−0.0446	0.0064	−0.4713
	(0.0074)	(0.0257)	(0.0115)	(1.764)
Arkansas	0.0007	−0.0506	0.0042	−0.4883
	(0.0090)	(0.2491)	(0.0140)	(2.146)
Florida	0.0042	−0.0813	0.0070	−0.5433
	(0.0076)	(0.2110)	(0.0119)	(1.833)
Georgia	0.0068	−0.1387	0.0074	−0.4364
	(0.0056)	(0.1537)	(0.0091)	(1.406)

Table 2. Continued

Price Series	Stock Market Model α	Stock Market Model β	Inflation Model α	Inflation Model β
Kentucky	0.0050	0.1341	−0.0104	2.711
	(0.0163)	(0.4390)	(0.0244)	(4.639)
Louisiana	−0.0032	0.0295	−0.0083	1.428
	(0.0092)	(0.2550)	(0.0142)	(2.189)
Mississippi	0.0014	−0.1374	−0.0001	0.2787
	(0.0082)	(0.2269)	(0.0133)	(2.047)
North Carolina	0.0004	0.2717	0.0088	−1.279
	(0.0074)	(0.2042)	(0.0120)	(1.849)
Oklahoma	−0.0044	−0.2978	0.0089	−4.186
	(0.0174)	(0.4680)	(0.0231)	(4.377)
South Carolina	0.0053	−0.0732	0.0088	−0.9844
	(0.0058)	(0.1598)	(0.0102)	(1.561)
Tennesee	0.0063	0.0150	0.0095	−1.285
	(0.0111)	(0.3069)	(0.0191)	(2.934)
Texas	0.0021	−0.1429	0.0014	0.1798
	(0.0088)	(0.2424)	(0.0138)	(2.128)
Virginia	0.0096	−0.2064	0.0069	−0.3218
	(0.0096)	(0.2656)	(0.0160)	(2.462)
Quarterly (Timber Mart South)				
Alabama	0.0008	0.2557	0.0042	0.3037
	(0.0190)	(0.2849)	(0.0289)	(1.546)
Arkansas	−0.0090	0.2690	0.0016	0.1667
	(0.0252)	(0.3782)	(0.0378)	(2.016)
Florida	0.0026	0.1450	0.0103	0.0743
	(0.0173)	(0.2607)	(0.0258)	(1.377)
Georgia	0.0144	0.0064	0.0152	−0.1161
	(0.0142)	(0.2131)	(0.0209)	(1.116)
Kentucky	−0.0105	0.6601	−0.0258	2.109
	(0.0313)	(0.4247)	(0.0606)	(4.259)
Louisiana	−0.0091	0.1260	−0.0250	1.477
	(0.0236)	(0.3540)	(0.0346)	(1.850)
Mississippi	0.0009	0.0331	−0.0021	0.5827
	(0.0228)	(0.3421)	(0.0344)	(1.837)
North Carolina	−0.0009	0.3216	0.0054	0.0218
	(0.0172)	(0.2585)	(0.0265)	(1.415)
Oklahoma	−0.0317	0.1339	0.0570	−6.643
	(0.0369)	(0.5010)	(0.0461)	(3.239)
South Carolina	0.0082	0.1048	0.0089	0.0120
	(0.0139)	(0.2086)	(0.0216)	(1.156)
Tennesee	0.0093	0.4465	0.0228	−0.6414
	(0.0200)	(0.3000)	(0.0337)	(1.799)
Texas	−0.0004	0.0951	−0.0140	1.371
	(0.0262)	(0.3942)	(0.0384)	(2.055)
Virginia	0.0171	0.0290	0.0299	−1.041
	(0.0169)	(0.3540)	(0.0268)	(1.430)
Quarterly (state data)				
Louisiana	0.0070	0.1846	0.0148	−0.2714
	(0.0065)	(0.1021)	(0.0099)	(0.6867)
Mississippi	0.0183	0.5447	0.0938	−3.809
	(0.0137)	(0.2182)	(0.0333)	(1.664)
Annual (state data)				
Arkansas	0.0376	0.0229	0.0623	−0.5256
	(0.0399)	(0.2390)	(0.0487)	(0.9162)
Louisiana	0.0431	−0.0212	0.0201	0.4629
	(0.0344)	(0.2243)	(0.0473)	(0.8234)
South Carolina	0.0286	0.1109	0.0277	0.3343
	(0.0277)	(0.1675)	(0.0328)	(0.6353)

Note: The models were estimated by ordinary least squares regression of the rate of stumpage price change on either the rate of change in the S&P 500 Index (the stock market model) or the rate of change in the consumer price index (the inflation model). Standard errors of the regression coefficients are given in parentheses.

Table 3. Serial Correlation Coefficients, Stock Market Model

	Lag					
Price Series	1	2	3	4	8	12
Monthly (Timber Mart South)						
Alabama	−0.088*	−0.066	−0.013	−0.067		0.172
Arkansas	−0.097*	0.091	0.050	−0.110		−0.036
Florida	−0.009*	−0.184*	0.062	−0.111		0.056
Georgia	−0.077*	−0.169	0.179	−0.032		0.125
Kentucky	−0.300*	0.066	−0.162	−0.065		−0.021
Louisiana	−0.149*	0.021	0.114	−0.158		0.114
Mississippi	−0.002*	−0.156	0.130	−0.090		0.002
North Carolina	−0.168*	−0.044	0.009	0.039		−0.092
Oklahoma	−0.212*	−0.079	0.092	−0.062		−0.009
South Carolina	−0.069*	−0.074	−0.017	−0.003		−0.051
Tennesee	−0.361*	0.137	−0.159	0.045		0.160
Texas	0.072	−0.206*	0.228*	0.007		0.039
Virginia	−0.315*	0.051	−0.004	−0.010		−0.079
Quarterly (Timber Mart South)						
Alabama	0.120	0.053	−0.072	−0.011	0.027	
Arkansas	0.239	−0.251	−0.222	0.145	0.029	
Florida	0.201	−0.048	0.050	−0.236	0.080	
Georgia	0.152	0.038	−0.002	−0.179	0.012	
Kentucky	−0.287*	−0.032	0.277	−0.324	−0.057	
Louisiana	0.115	−0.340*	−0.087	0.222	0.034	
Mississippi	0.155	−0.135	−0.055	−0.090	0.022	
North Carolina	0.295	−0.094	−0.217	−0.215	0.055	
Oklahoma	0.064	0.040	−0.009	−0.014	−0.172	
South Carolina	0.180	−0.130	0.105	−0.167	0.025	
Tennesee	0.012	−0.066	−0.078	0.215	−0.022	
Texas	0.255	−0.251	−0.174	0.301	0.080	
Virginia	0.212	0.005	−0.084	−0.104	0.014	
Quarterly (state data)						
Louisiana	0.225	0.195*	0.104	−0.076	0.040	
Mississippi	−0.076*	−0.022	0.007	−0.087	−0.095	
Annual (state data)						
Arkansas	0.062	−0.029	−0.148	−0.059		
Louisiana	0.232	0.122	0.086	−0.002		
South Carolina	0.189	−0.128	−0.014	0.125		

Note: An asterisk (*) indicates that the correlation coefficient is two standard errors from the expected value (0.25 for first lag and 0.0 for all subsequent lags).

for both the stock- and inflation-based models consistently exhibited negative correlation at the first lag (the coefficients were significantly less than 0.25). In states where the relationship at the one-month lag was relatively weak, there was often negative correlation at the two-month lag (e.g., Mississippi, Texas, and Florida). Thus, a departure from the equilibrium rate of monthly price change tended to be corrected the next month by a departure in the opposite direction. The correction sometimes persisted for two months. Plots of the autocorrelation and partial autocorrelation functions indicated that the relationships follow either first- or second-order moving-average processes having memories of only one or two periods, respectively. Thus, studying the past behavior of monthly southern pine prices can help predict future departures from equilibrium rates of price change, but for only one or two months in advance.

The serial dependence in the monthly residuals is largely eliminated when departures from equilibrium rates of change are examined over quarters. Although nearly all of the quarterly series calculated from monthly Timber Mart South prices retained their negative correlation at the first lag (the coefficients were less than 0.25), only the coefficients for Kentucky were statistically significant. Among the quarterly and annual series reported by state agencies, only the quarterly Mississippi prices exhibited a negative correlation at the first lag. It appears that studying departures from equilibrium rates of price change over quarters or years can not help to predict future quarterly or annual departures.

There is, however, cause to be wary of the

serial correlation results. Calculation of skewness and kurtosis measures for each series of regression residuals indicated that most of them are not normally distributed. Many of the distributions are skewed (in some cases to the right and in others to the left). Even more are leptokurtotic (fat-tailed); that is, there were larger numbers of relatively large deviations from expected changes than would occur for a normal distribution. This apparent lack of normality implies that the results of the serial correlation tests may be misleading and should be validated with the nonparametric turning point tests.

Table 5 compares the observed number of turning points in each series of regression residuals with the number expected from an averaged, random series. The turning point test was less likely than the serial correlation test to reject market efficiency. For example, whereas the serial correlation test rejected market efficiency for twelve of the thirteen series of monthly stock-based residuals, the turning point test rejected efficiency for only four of the thirteen series. However, in general the turning point results confirm the results of the serial correlation analysis.

Conclusions

The results of these tests for weak-form market efficiency depend on the time interval over which departures from equilibrium rates of stumpage price change are measured. On annual and quarterly bases, departures from equilibrium rates were serially independent, indicating that stum-

Table 4. Serial Correlation Coefficients, Inflation Model

	Lag					
Price Series	1	2	3	4	8	12
Monthly (Timber Mart South)						
Alabama	−0.072*	−0.054	−0.031	−0.077		0.131
Arkansas	−0.101*	0.038	0.112	−0.215*		−0.036
Florida	−0.041*	−0.197*	0.091	−0.108		0.022
Georgia	−0.159*	−0.143	0.117	0.067		0.102
Kentucky	−0.225*	−0.143	−0.153	−0.175		−0.099
Louisiana	−0.139*	−0.071	0.111	−0.152		0.161
Mississippi	−0.017*	−0.178*	0.063	−0.063		0.019
North Carolina	−0.193*	−0.000	−0.022	0.047		−0.104
Oklahoma	−0.278*	−0.076	0.083	−0.047		−0.028
South Carolina	−0.201*	0.064	−0.146	0.077		−0.002
Tennesee	−0.381*	0.068	−0.016	−0.054		0.109
Texas	0.039*	−0.211*	0.176	0.014		0.072
Virginia	−0.357*	0.070	−0.061	−0.031		−0.105
Quarterly (Timber Mart South)						
Alabama	0.079	0.033	−0.085	−0.062	0.062	
Arkansas	0.136	−0.246	−0.264	0.156	−0.023	
Florida	0.202	0.014	−0.032	−0.279	0.092	
Georgia	0.143	0.053	0.002	−0.186	0.012	
Kentucky	−0.174*	−0.061	0.209	−0.388	0.160	
Louisiana	0.055	−0.384*	−0.120	0.275	0.021	
Mississippi	0.098	−0.157	−0.077	−0.099	0.100	
North Carolina	0.290	−0.024	−0.268	−0.302	0.087	
Oklahoma	−0.025	0.081	−0.174	−0.066	−0.212	
South Carolina	0.133	−0.144	0.115	−0.226	0.055	
Tennesee	0.009	−0.050	−0.101	0.153	0.038	
Texas	0.209	−0.311	−0.237	0.293	0.021	
Virginia	0.077	0.076	−0.122	−0.036	0.045	
Quarterly (state data)						
Louisiana	0.234	0.194*	0.074	−0.090	0.039	
Mississippi	−0.090*	−0.031	−0.017	−0.036	0.005	
Annual (state data)						
Arkansas	0.081	0.025	−0.093	−0.045		
Louisiana	0.206	0.074	0.041	−0.019		
South Carolina	0.098	−0.267	−0.095	0.094		

Note: An asterisk (*) indicates that the correlation coefficient is two standard errors from the expected value (0.25 for first lag and 0.00 for all subsequent lags).

Table 5. Turning Points

Price Series	Stock Market Model		Inflation Model	
	Expected	Observed	Expected	Observed
Monthly (Timber Mart South)				
Alabama	71.27	78	76.71	84
Arkansas	71.27	77	76.71	83
Florida	71.27	76	76.71	81
Georgia	71.27	78	76.71	88*
Kentucky	47.11	56*	52.55	61*
Louisiana	71.27	77	76.71	81
Mississippi	71.27	82*	76.71	89*
North Carolina	71.27	84*	76.71	91*
Oklahoma	47.11	59*	52.55	65*
South Carolina	71.27	76	76.71	84
Tennesee	71.27	77	76.71	86
Texas	71.27	74	76.71	82
Virginia	71.27	78	76.71	88*
Quarterly (Timber Mart South)				
Alabama	23.56	24	25.37	26
Arkansas	23.56	21	25.37	23
Florida	23.56	28	25.37	28
Georgia	23.56	23	25.37	26
Kentucky	15.70	15	17.52	17
Louisiana	23.56	19	25.37	21
Mississippi	23.56	19	25.37	21
North Carolina	23.56	21	25.37	28
Oklahoma	15.70	17	17.52	18
South Carolina	23.56	20	25.37	22
Tennesee	23.56	21	25.37	22
Texas	23.56	19	25.37	21
Virginia	23.56	25	25.37	28
Quarterly (state data)				
Louisiana	75.50	81	75.50	81
Mississippi	25.97	31	25.97	27
Annual (state data)				
Arkansas	19.33	20	19.33	22
Louisiana	17.52	21	17.52	21
South Carolina	21.14	24	21.14	24

Note: An asterisk (*) indicates that the observed number of turning points is at least two standard errors greater or lesser than the expected number.

page markets are weak-form efficient. Weak-form information can not be used to produce a better estimate of the price of stumpage a quarter or more into the future than the capitalized current price. On a monthly basis, however, markets for southern pine sawtimber stumpage do not pass this test. A departure from the equilibrium rate of stumpage price change over one month tends to be followed by a departure in the opposite direction during the next month.

It is important to note that the weak-form efficiency test implicitly assumes that movement of stumpage in and out of storage is frictionless; that is, that timber sale plans can be instantaneously adjusted at no cost. This assumption may not be reasonable. The time and cost involved in consumating a timber sale might produce short-run friction in stumpage markets. If this is so, then the failure of stumpage prices to adjust instantaneously to new information such as demand or interest rate shocks might indicate that the costs of adjustment exceed the possible economic gains, not that stumpage markets inefficiently process weak-form information.

These findings have important implications for three areas of forest economics. First, if stumpage markets are weak-form efficient, then there can be no gain from using past price movements to play the market in timing timber harvests. This appears to be the case for southern pine sawtimber if the time required to complete a timber sale is a quarter or longer. If, however, a timber sale can be consumated within a month, our results are less certain, suggesting that price-responsive models of the Norstrom/Lohmander/Brazee-Mendelsohn type for the optimal time to harvest

timber could possibly produce some economic gains. However, data on adjustment costs would be needed for this type of analysis.

Second, the capital asset pricing model assumes that asset markets pass the weak-form efficiency test. If the market for an asset is not weak-form efficient, then the expected return on the asset is not described by the CAPM relationship. Consequently, a CAPM for forest assets based on short-run, monthly data is inevitably misspecified. This specification error might account for the wide differences observed in CAPM parameter estimates derived from monthly and annual data (Binkley and Washburn 1988b).

Finally, for at least thirty years economists have urged the USDA Forest Service and other similar public agencies to alter timber supply in response to changes in stumpage prices. When prices are high, the argument goes, the public timber agencies should offer more timber, and when prices are low, they should withdraw timber from the market. Such a policy would presumably increase public timber revenues, and in markets where the public agencies have monopsony power, would tend to stabilize prices.

Two considerations undermine the implementation of such a policy. First, achieving these putative gains requires that stumpage markets are inefficient; otherwise, there is no way to know if current prices are high or low. Yet, the results of this study indicate that markets for pine stumpage in the South pass the standard tests for weak-form informational efficiency. All of the profits which can be obtained from a price-responsive sales policy on the southern national forests have already been extracted from the system. Prices fluctuate in a socially optimal manner.

Second, even if stumpage markets in other regions are found to be inefficient, the Forest Service has only a limited capacity to influence, in the short run, the amount of timber which is harvested from the national forests (Adams, Binkley, and Cardellichio). The Forest Service sells timber but does not actually harvest it. Typical timber sales contracts provide a period of several years for the purchaser to harvest the sale. As a result of this sales procedure, timber sold by the Forest Service enters an inventory of uncut timber under contract. Within the confines of expiration terms and other contract provisions, purchasers may harvest timber out of this inventory whenever they desire. Altering the quantity of timber sold into the inventory has only an indirect effect on the quantity of timber actually supplied from the national forests in any one year. Consequently, harvest levels are already subject to market forces, and moves to shorten contract length, reduce the size of the inventory of uncut volume under contract, or otherwise limit harvest flexibility could impair the efficiency of stumpage markets. For these reasons, failing to adjust Forest Service sales levels in the face of fluctuating timber prices may not be economically irrational.

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Bootstrapping in Applied Welfare Analysis

Catherine L. Kling and Richard J. Sexton

Bootstrapping procedures are used to estimate the statistical properties of common empirical welfare measures. Results from a Monte Carlo experiment indicate that welfare estimates such as Marshallian consumer surplus often exhibit significant bias. Standard errors of welfare estimates are found to often exceed the magnitude of the point estimate for typical cross-section data sets and are generally larger than the difference between comparable Hicksian and Marshallian measures. Precision of welfare estimates can be markedly enhanced through generating larger data sets, obtaining better model fits, and through imposition of innocuous inequality restrictions on the demand function parameters.

Key words: bootstrapping, consumer welfare, Monte Carlo, nonmarket valuation, recreation demand, statistical inference.

This paper investigates the use of bootstrapping procedures to address problems in applied welfare analysis. Although the primary focus is on applications in recreation demand, the methods are applicable to a number of fields. The prototype methodology in applied welfare analysis involves statistical estimation of a demand function or system of demand functions. The estimated model is then used to calculate point estimates of Marshallian consumer surplus or exact Hicksian welfare measures of compensating or equivalent variation. Recommendations for policy or project decision making are based on the value of these point estimates.

A number of different welfare measures are relevant depending upon the type of analysis. For example, the valuation of recreational facilities and amenities requires an estimate of the total area under a demand curve (e.g., Ziemer, Musser, and Hill; Bockstael and Strand). In studies of agricultural policies, industrial organization, and regulation, the welfare effects of a small price change, particularly the deadweight loss, are at issue (e.g., Parker and Connor; Kaiser, Streeter, and Liu).

Welfare measures computed from estimated demand function parameters are random variables with nontrivial and usually unknown probability distributions. This basic statistical fact has become a subject of increasing concern among welfare analysts [Bockstael, Hanemann, and Strand (BHS); Graham-Tomasi, Adamowicz, and Fletcher (G-TAF); Adamowicz, Fletcher, and Graham-Tomasi (AFG-T), and Smith] for two fundamental reasons: (*a*) welfare estimates computed from point estimates of demand are often biased estimators of the "true" welfare (BHS, G-TAF, Smith); (*b*) because the probability distributions of the welfare estimators are usually unknown, it has not been possible to evaluate the statistical reliability of welfare estimates through computation of standard errors or confidence intervals or to make basic statistical inferences including hypothesis tests. In particular, the usual measures of goodness of fit such as R^2 or t-statistics need not imply corresponding accuracy of welfare estimators.

Basing recommendations for policy and project decisions on biased welfare estimates about which no other statistical properties are known does not seem desirable. The goal of this paper is to suggest improvements in this basic methodology using bootstrapping techniques. Bootstrapping permits the assessment of variability in an estimate using only the data at hand by

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resampling the original observations. A variation of the bootstrapping methodology has recently been introduced into applied welfare analysis by G-TAF and AFG-T.

This paper illustrates and analyzes the use of bootstrapping to estimate the bias and precision of any empirical welfare measure. The paper extends the work of G-TAF and AFG-T in a number of contexts: (*a*) it uses a bootstrap that resamples from the empirical error distribution rather than from a normal distribution; (*b*) it analyzes a variety of welfare estimators rather than just the Marshallian measure of total consumer surplus; (*c*) it shows how to construct confidence intervals for welfare estimators that are unlikely to be normally distributed; (*d*) it analyzes the bootstrap in a Monte Carlo framework wherein the true values of the welfare measures are known and the performance of the bootstrap can be evaluated in a variety of empirical settings; and (*e*) an adaptation of the basic bootstrap methodology using inequality constraints is proposed and evaluated as a means of reconciling some significant problems raised in the G-TAF and AFG-T analyses.

The next section describes in more detail some basic results concerning the properties of welfare estimators computed from common demand functions. The bootstrap methodology, including the adaptation, is discussed in the following section. The Monte Carlo experiment to illustrate and evaluate use of the bootstrap is then described and analyzed. The paper closes with conclusions and recommendations.

Consumer Welfare Estimators

To make the scope of this study manageable, it focuses specifically upon the linear and semilog demand functions. These are the most commonly used functional forms in recreation analysis [McConnell, Bockstael and Strand (BS)], and both are compatible with utility maximization (Hanemann).[1] However, the problems which motivate this paper and the results we obtain should apply to any utility theoretic demand function.

The demand functions are as follows:

$$(1) \qquad X_i = a + bP_i + cY_i + u_i,$$

$$(2) \qquad X_i = \exp(a + bP_i + cY_i + u_i),$$

where X_i is the quantity consumed of the relevant good by the ith individual, P_i and Y_i are, respectively, a nonstochastic normalized price and the consumer's income. Use of the same parameter symbols for both functions is for convenience and does not imply that the parameters are identical. It is assumed throughout that the u_i are identically and independently distributed with variance σ^2.

Welfare calculations have been alternatively based on the actual X_i or on only the systematic portion, X_i', of demand, where for the linear model,

$$(3) \qquad X_i' = a + bP_i + cY_i = X_i - u_i.$$

Bockstael and Strand provide guidance on the choice between X_i and X_i' based on alternative interpretations of the error term, u_i.

Table 1 summarizes welfare formulas for both the linear and semilog functions based on the actual X_i. Subscripting to denote individuals is omitted from the table and from the subsequent text where appropriate. The small price change for formulas in rows B, C, E, and F is denoted by $k = P1 - P0$, and

$$(4) \qquad X1 = a + bP1 + cY + u.$$

Rows A–C in table 1, respectively, provide the Marshallian surplus formulas for the total consumer surplus, the small price change surplus, and the small price change deadweight loss. Rows D–F provide the corresponding Hicksian compensating variation formulas. Column 2 identifies the graphical depiction of each area in figure 1.

In the usual sampling-theoretic interpretation, a, b, and c are nonrandom parameters and the X_i' are also nonrandom. The actual quantities, X_i, however, are random due to the stochastic error term. It follows then that welfare measures based on the true parameters and the X_i' are nonstochastic under the sampling theoretic interpretation but that measures based on the actual X_i are stochastic (BHS). For example, for the linear demand, the expected true total Marshallian consumer surplus (cs^T) given the parameters a, b, and c is

$$(5) \quad E[cs^T] = \frac{(a + bP + cY)^2 + \sigma^2}{-2b} = \frac{X'^2 + \sigma^2}{-2b}.$$

In empirical work, the parameters a, b, and c, and the disturbance vector $u = \{u_1, \ldots, u_n\}$ must be replaced in table 1 and equations (3)

[1] The double log function is also popular, but it is excluded here in part because the total consumer surplus measure may be unbounded for this function.

Table 1. Alternative Welfare Measures for the Linear and Semilog Demand Functions

Welfare Measure	Fig. 1 Area	Linear	Semilog
A Total *CS* (*cs*)	ABP_0	$\dfrac{x_0^2}{-2b}$	$\dfrac{x_0}{-b}$
B Small *CS* (*CSS*)	P_0P_1CD	$\dfrac{x_1^2 - x_0^2}{2b}$	$\dfrac{x_1 - x_0}{b}$
C *DWL CS* (*CSD*)	ECB	$-\dfrac{k^2b}{2}$	$\dfrac{x_1(1 - kb) - x_0}{b}$
D Total *CV* (*CVT*)	FBP_0	$-\dfrac{b}{c^2} + \exp\left(c\left(\dfrac{-(a + e + c_y)}{b} - p_0\right)\right)\left[\dfrac{x_0}{c} + \dfrac{b}{c^2}\right]$	$-\dfrac{1}{c}\ln\left(1 + \dfrac{c}{b}x_0\right)$
E Small *CV* (*CVS*)	P_0P_1DB	$-\left[\dfrac{b}{c^2} + \dfrac{x_1}{c}\right] + \exp(ck)\left[\dfrac{x_0}{c} + \dfrac{b}{c^2}\right]$	$-\dfrac{1}{c}\ln\left[1 + \dfrac{c}{b}(x_0 - x_1)\right]$
F *DWL CV* (*CVD*)	GDB	$\left[\dfrac{cx_0 + b}{c^2}\right][\exp(ck)(1 - ck) - 1]$	$-\dfrac{1}{c}\ln\left[1 + \dfrac{c}{b}(x_0 - x_1)\right] + \dfrac{kbx_1}{-b + c(x_1 - x_0)}$

and (4) by statistical estimates denoted by $\hat{\theta} = \{\alpha, \beta, \gamma\}$, and $\epsilon = \{\epsilon_1, \ldots, \epsilon_n\}$, respectively, where $\epsilon_i = X0_i - \alpha - \beta P0_i - \gamma Y_i$. Thus,

$$\hat{X}_i = \alpha + \beta P_i + \gamma Y_i. \tag{3'}$$

Because α, β, γ, and, in turn, $\hat{X}$ are random variables, the various welfare estimators are also random variables. Most involve some ratio of random variables regardless of whether X or $\hat{X}$ is used in the calculations. In general, the mean

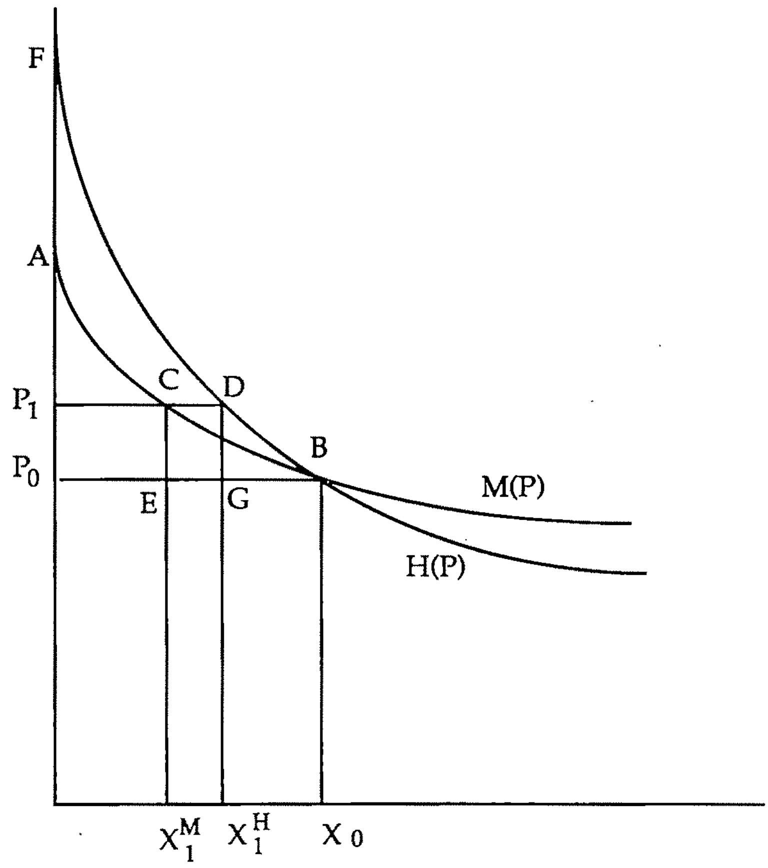

Figure 1. Alternative welfare measures

and variance for a ratio of random variables cannot be expressed analytically in terms of the moments of the two random variables. In fact, the mean and variance for the ratio may not exist (Mood, Graybill, and Boes). For example, the moments of the Marshallian consumer surplus estimator for either the linear or semilog models will not exist unless the price coefficient is restricted away from zero.

In cases where the moments of welfare estimators are known to exist, approximation formulas can be derived based on Taylor's series expansions. For example, approximation formulas for the estimated total Marshallian surplus, $\hat{cs}$, from the linear demand are as follows:

$$\text{(6)}\quad E[\hat{cs}] \simeq \frac{X'^2 + \sigma^2}{-2b} + \frac{X'^2}{-2b}\left[\frac{\text{Var}\beta}{b^2} - \frac{2\text{Cov}(\beta, X)}{X'b}\right],$$

$$\text{(7)}\quad \text{Var}[\hat{cs}] \simeq \frac{X'^2}{b^2}\sigma^2 + \frac{X'^4}{4b^4}\text{Var}\beta - \frac{X'^3}{b^3}\text{Cov}(\beta, X).$$

Equation (6) represents a second-order Taylor's series expansion around $E[X] = X'$, $E[\beta] = b$, while (7) is derived from a first-order Taylor's series expansion around X', b.[2]

That $\hat{cs}$ is a biased estimate of cs^T is a general consequence of $E[R/S] \neq E[R]/E[S]$ for any random variables R and S. As such, bias also exists for point estimates of the other welfare measures in table 1 (except for the linear demand deadweight loss) regardless of whether the X_i or $\hat{X}_i$ are used in the calculations. It has been suggested that the Taylor's series approximation of $E[\hat{cs}]$ in (6) may be useful in correcting for the bias (BHS, Kealy and Bishop). For the linear demand this correction is made by computing and reporting

$$\text{(8)}\quad \hat{cs}^{\text{corrected}} = \hat{cs} - (\hat{X}'^2/-2\beta)[\text{Var}\beta/\beta^2 - 2\text{Cov}(\beta, X)/\hat{X}'\beta],$$

where the second term is the correction factor based on the Taylor's series approximation of $E[\hat{cs}]$ in (6) and the sample estimators $\hat{X}$ and β are substituted for X' and b, respectively, in the $E(\hat{cs})$ approximation.

[2] The formulas in (6) differ from counterparts in the literature (BHS, Kealy and Bishop) apparently because the prior authors expanded $\hat{cs}$ around $E[X^2] = X' + \sigma^2$ rather than $E[X]$ and omitted the covariance term.

However, the accuracy of the second-orde approximation of $E[\hat{cs}]$ has been questioned b G-TAF who suggest that errors from use of th second-order approximation (6) are potentiall large for both the linear and semilog forms. Thei conclusion is based on analysis of a single dat set and a single welfare estimator, Marshallia surplus, and its generality is one focus of th Monte Carlo analysis here. A similar set of con cerns would apply to the approximate varianc formula (7), although they are not addressed i this paper.

Bootstrapping in Applied Welfare Analysis

In the context of applied welfare analysis, th bootstrapping approach evolves in the followin steps (see generally Freedman and Peters):

1. A functional form for consumer demand such as (1) or (2), is chosen. The disturbance u_i are assumed i.i.d. with mean zero. Normalit of the u_i need not be assumed. The model i estimated on the sample data. The estimated pa rameters, α, β, and γ are used to compute welfare estimate, $\hat{w}$.

2. The regression residuals ϵ_i (which are es timates of the true disturbances, u_i) are com puted and used to create a distribution, ϕ. Eac ϵ_i, $i = 1, \ldots, n$, has probability mass $1/n$ i ϕ.[3]

3. New quantities $\{X_1^*, \ldots, X_n^*\}$ are generate by resampling from the residuals, e.g., for th linear model, $X_i^* = \alpha + \beta P_i + \gamma Y_i + \epsilon_i^*$, wher ϵ_i^* is chosen by random draw with replacemen from ϕ.

4. New parameter estimates, $\hat{\theta}^* = \{\alpha^*, \beta^*$ $\gamma^*\}$ and disturbance vector $\xi_i = \{\xi_1, \ldots, \xi_n\}$ ar generated from regressing X^* on P and Y an used to compute a new welfare estimate, $\hat{w}^*$.

5. Steps 3 and 4 are repeated by redrawin some large number, T, of times from ϕ to gen erate an empirical distribution for $\hat{w}^*$. This dis tribution characterizes the statistical uncertaint associated with $\hat{w}$.[4]

Let η denote the distribution of the $\hat{w}^*$ gen erated from the above process. The mean of thi distribution is denoted as $\bar{w}^* = (1/T)\Sigma_t\hat{w}_t^*$. Th

[3] Freedman and Peters (p. 99) suggest inflation of the residual to compensate for the deflation of the residuals in fitting. The suggested inflation factor is employed in the subsequent analysi in this paper.

[4] Variations on this prototype methodology can be employed whe the underlying data is censored or truncated as is common in re reation data sets. See generally Efron (1981a).

difference between $\bar{w}^*$ and the point estimate of welfare provides an estimate, B, of the bias:

$$(9) \qquad B = \bar{w}^* - \hat{w}.$$

That is, in the bootstrap simulation, $\hat{w}$ is the true welfare measure so the average deviation from $\hat{w}$ of the bootstrap-generated $\hat{w}_t^*$ measures the bias. The bootstrap-generated B is compared to Taylor's series estimates of the bias in the next section.

Likewise, Var[$\hat{w}$] can be estimated by computing $E[\hat{w}^{*2}] = (1/T)\Sigma\hat{w}_t^{*2}$, $E[\hat{w}^*] = \bar{w}^*$, and invoking the usual formula:

$$(10) \qquad \mathrm{Var}\,[\hat{w}^*] = E[\hat{w}^{*2}] - (E[\hat{w}^*])^2.$$

A crude confidence interval may be constructed from (10) by assuming that the $\hat{w}$ are distributed normally and computing, for example, $\hat{w} \pm 1.645(\mathrm{Var}[\hat{w}^*])^{1/2}$ to obtain a putative 90% interval for w. However, it is questionable whether the $\hat{w}$ will be distributed normally, particularly in small samples (Hayya, Armstrong, and Gressis; Efron (1981b)). A distribution-free alternative would be $\hat{w} \pm 3.16(\mathrm{Var}[\hat{w}^*])^{1/2}$ based on Chebychev's inequality.

Efron (1981b, 1987), however, has suggested that better confidence intervals can be obtained by more fully utilizing the information contained in η. One possibility is to construct a (1–2δ percent confidence interval for w by deleting the outer δ tails from η.

G-TAF and AFG-T assume that the u_t are distributed normally and generate a vector of disturbances ϵ^* directly from a normal $(0, \hat{\sigma}^2)$ distribution, where $\hat{\sigma}^2$ is the sample variance, rather than from the empirical distribution of the residuals. The merit of this approach is analyzed below using Monte Carlo analysis.[5]

An apparent problem in the AFG-T and G-TAF analyses is that the bootstrap-generated data occasionally produced parameters yielding implausible welfare estimators. Specifically, draws generating absolutely small negative values for β yield very large values of willingness to pay, quite possibly in excess of income. Positive values for β may also be generated, implying negative willingness to pay. Such results are counterintuitive and inconsistent with the underlying economic theory. Yet because these implausible estimators may be very large in absolute value relative to the magnitude of the other bootstrap-generated welfare estimates, they can easily dominate calculations of bias and also cause bootstrap-estimated variances of welfare to be very large. These outcomes most likely reflect an estimator which does not have finite moments (Smith).

The modification proposed and analyzed here eliminates aberrant bootstrap draws using inequality restrictions on the demand function parameters. Specifically, the requirement that willingness to pay must be bounded by zero and total income is imposed:

$$(11) \qquad 0 < \hat{w}_i < Y_i, \text{ for all } i = 1, \ldots, n.$$

These restrictions on the $\hat{w}_i$ translate into inequality restrictions on the demand function parameter vector $\hat{\theta} = \{\alpha, \beta, \gamma\}$. In addition to the restrictions in (11), the modification imposes integrability conditions (BHS) on the demand functions,

$$(12) \qquad X_i < b/c, \text{ for all } i = 1, \ldots, n,$$

for both the linear and semilog functions. These conditions would seem to comprise the least restrictive set of prior information to impose on the analysis. Tighter bounds on the $\hat{w}_i$ would certainly be realistic in many applications. These inequality restrictions might be imposed via quadratic programming at each bootstrap trial (Judge and Takayama), but the distribution theory for this estimator is lacking (Geweke) and the procedure may be inordinately expensive.

An alternative is to impose the restrictions using Bayesian methods wherein restrictions are summarized in the prior density function for θ, $P(\theta)$. The improper prior which imposes the restrictions in (11) and (12) is

$$(13) \qquad P(\theta) = \begin{cases} 1 \text{ if } 0 < w_i < Y_i \text{ and } X_i < b/c,\ i = 1, \ldots, n, \\ 0 \text{ otherwise.}^6 \end{cases}$$

[5] Normality of the u_t is not needed for OLS to be the best linear unbiased estimator, but it is usually invoked to justify classical statistical inference. Bootstrapping provides an alternative to these methods, so it may be unnecessarily restrictive to invoke normality of the u_t in conducting the bootstrap trials.

[6] The compensating variation measures defined in table 1 and used in the Monte Carlo analysis are willingness to accept measures which are not necessarily bounded by income. Therefore, in imposing the inequality constraints, Hicksian equivalent variation measures (which do correspond to willingness to pay in this case) were calculated and employed. A reviewer noted that welfare measurement in the case of corner solutions may complicate the imposition of the constraints. Finally, the measure of income used in the constraints can be an issue since welfare measures may not depend on current income alone.

From Bayes' theorem, this prior density function, when combined with the sample likelihood function $L(\theta|X, P, Y)$, yields a posterior density function,

$$(14) \quad P(\theta|X, P, Y) \propto P(\theta)L(\theta|X, P, Y),$$

where α denotes proportionality. The posterior density is defined only over the parameter space consistent with the restrictions. In the usual Bayesian framework, the regression disturbances ϵ are assumed to be normally distributed, and the likelihood is, consequently, easy to define. However, the posterior density in (14) often cannot be integrated to obtain its moments and Monte Carlo integration (Kloek and van Dijk, Geweke) is used as an alternative. With Monte Carlo integration, a large number of draws of $\hat{\theta}$ are made from the posterior distribution. The mean of these draws is usually used as a point estimate of θ (Geweke). Work applying these methods to welfare estimators has recently been conducted by Adamowicz, Graham-Tomasi, and Fletcher.

The assumption of normal sampling may be an unwarranted feature of the approach (Chalfant and White). An alternative pursued here follows the suggestion of Boos and Monahan to replace the normal distribution likelihood in (14) with the bootstrap estimate of the sampling density of $\hat{\theta}$, to be denoted $\hat{L}(\hat{\theta}|X, P, Y)$:

$$(14') \quad \hat{P}(\theta|X, P, Y) \propto P(\theta)\hat{L}(\hat{\theta}|X, P, Y).$$

Given the prior in (13), the posterior in (14′) is estimated from only those bootstrap trials satisfying the inequality restrictions. The final step in the procedure is to estimate a posterior distribution for w by computing the $\hat{w}^*$ for only those bootstrap trials in which the $\hat{\theta}^*$ satisfy the restrictions in (13).

The bootstrapping approach to incorporating inequality restrictions is quite similar to the Monte Carlo integration methodology described earlier in that the posterior distribution for θ in either case is estimated from only those $\hat{\theta}$ satisfying the restrictions, with nonconforming trials being discarded. The essential difference in the approaches is that bootstrapped data sets, not random number generators, are used to generate the $\hat{\theta}^*$, thus avoiding the need to make possibly erroneous assumptions about the distribution of θ.[7]

[7] It should also be noted that interpretation of the regression model is quite different in Bayesian vs. sampling-theoretic frameworks (Griffiths). For example, whereas θ is treated as nonstochastic in the sampling-theoretic framework, uncertainty about the unknown θ is represented in terms of a probability distribution, e.g., (13), under a Bayesian interpretation.

The Monte Carlo Experiment

The preceeding discussion has raised a number of questions about the practice of applied welfare analysis, including:

(*a*) How significant is the bias of point estimates of welfare, and how accurately can the bootstrap results and/or the second-order approximation of $E[\hat{w}]$ predict this bias? In turn, how is the answer to this question affected by features of the data sample including the sample size, distribution and variance of the u_i, and the share of total consumer surplus relative to the total budget?

(*b*) How is the precision of welfare estimators affected by the parameters of the data sample described above?

(*c*) How do the answers to questions (*a*) and (*b*) vary among the alternative welfare estimators listed in table 1?

(*d*) Is the AFG-T simplification of the bootstrap methodology appropriate?

(*e*) Is the tendency of the bootstrap to yield implausible parameter draws and, in turn, welfare estimates ameliorated by introducing inequality restrictions?

(*f*) Are the bias and precision of welfare estimators significantly affected by the choice of functional form?

The simulation experiment to analyze these issues involved construction of sixteen data sets for both the linear and semilog functional forms. For each function, values were chosen for the parameters a, b, and c. Price (travel cost) and income data (P_i, Y_i) were taken from a Cheasapeake Bay beach survey conducted by Research Triangle Institute for the University of Maryland (BHS). Given values for a, b, c, and the P_i and Y_i, quantity variables, X_i, were constructed for each functional form using equations (1) and (2) by randomly drawing the u_i from an appropriate distribution. The data sets are differentiated based on the following four criteria: (*a*) distribution of the u_i—normal versus uniform, (*b*) magnitude of the error variance—large versus small, (*c*) sample size—25 versus 100 observations, (*d*) magnitude of the welfare measures—large versus small, where large w_i were obtained by increasing the base values of a, b, and c. Thus, each data set was characterized by a unique choice among these four criteria. Exhausting the possible combinations produced the sixteen data sets for each functional form.

For each data set, the true values of welfare were computed for each welfare measure using

the table 1 formulas. Welfare was computed for each individual and then averaged over the sample in accord with standard practice.

Point estimates α, β, and γ, and residuals ϵ_i were obtained for each data set using ordinary least squares (OLS). Given the properties of each data set, the OLS estimators are best linear and unbiased. The estimated parameters and residuals were then used to produce point estimates of welfare following the same process used to compute the true welfare. These estimates correspond to what an applied researcher would obtain. As noted, they are expected to be biased, and no other measures of their reliability would normally be provided. To test the second-order approximation to $E[\hat{w}]$, the adjustment to the $\hat{w}$ given in (8) were also computed for each data set.

The final steps in the simulation experiment involved conducting the bootstrap trials. Three alternative bootstrap procedures were employed on each data set: (*a*) The prototype bootstrap involving resampling from the empirical distribution of residuals, (*b*) The modified bootstrap with inequality restrictions, and (*c*) The AFG-T, G-TAF normal-distribution bootstrap involving sampling the ϵ_i from an $N(0, \hat{\sigma}^2)$ distribution.

One hundred successful bootstrap trials were obtained for each procedure. Thus, more than 100 repetitions were often needed for the bootstrap with Bayesian priors because trials where parameter estimates did not meet the restrictions were omitted. The 100 sets of parameter vectors and welfare estimators obtained for each approach were then used to compute B, Var$[\hat{w}]$, and confidence intervals.

Results

Table 2 contains results from OLS estimation for the first eight data sets for each functional form. The table also contains summary information on the characteristics of these data sets. Data sets 9–16 involved the large welfare measures (criteria 4 above). For brevity, results for these data sets are omitted from the tables, although whenever appropriate mean values are reported for both data sets 1–8 and 9–16. The first four linear and semilog data sets are similar to typical recreation demand data; the R^2's are fairly low, ranging from 0.13–0.53, the *t*-statistics are generally significant, but not extremely large, and consumer surplus constitutes a relatively small part of the consumer's total budget.

The Bias in Welfare Estimates

Table 3 compares estimates of the bias of $E[\hat{cs}]$ from the three alternative bootstrap methods for both the linear and semilog models. The first column in each table reports the actual bias as a percentage of the true welfare measure, i.e.,

Table 2. OLS Estimation Results for the Linear and Semilog Data Sets

	Description			Regression Results				
Data Set	Variance	Sample Size	Distribution	β	*t*-ratio	γ	*t*-ratio	R^2
Linear Model								
1	lg	100	nor	−0.07	−2.99	.00004	6.78	.35
2	lg	25	nor	−0.06	−1.30	.00004	2.03	.15
3	lg	100	uni	−0.12	−3.18	.00004	4.51	.22
4	lg	25	uni	−0.15	−2.16	.00003	0.78	.13
5	sm	100	nor	−0.09	−14.14	.00004	24.66	.89
6	sm	25	nor	−0.09	−7.60	.00005	8.20	.85
7	sm	100	uni	−0.09	−7.26	.00004	12.05	.66
8	sm	25	uni	−0.10	−4.93	.00003	3.24	.60
Semilog Model								
1	lg	100	nor	−0.03	−7.17	.000002	8.02	.53
2	lg	25	nor	−0.02	−2.55	.000001	0.31	.17
3	lg	100	uni	−0.03	−5.19	.000008	4.14	.30
4	lg	25	uni	−0.01	−1.08	.000018	2.70	.23
5	sm	100	nor	−0.03	−15.71	.000010	21.93	.88
6	sm	25	nor	−0.02	−8.01	.000030	22.35	.96
7	sm	100	uni	−0.02	−8.56	.000010	13.06	.71
8	sm	25	uni	−0.02	−3.54	.000011	5.18	.63

Table 3. Percentage Biases in Total Consumer Surplus: Actual and Bootstrap Estimates

Data Set	Actual	Bootstrap Estimates			Taylor's Series
		Prototype	Modified	Normal	
Linear model					
1	34	−335	39	32	14
2	58	−105	46	−764	89
3	−15	9	11	13	7
4	−34	5	44	13	13
5	9	1	1	0	1
6	3	2	2	0	2
7	8	2	2	2	2
8	−5	3	3	3	4
Mean square pct. error[a]	30.7	103.6	35.1	216.7	22.5
Semilog model					
1	−15	2	2	2	
2	3	25	22	64	
3	−40	1	1	2	
4	59	−49	106	367	
5	−4	−1	−1	1	
6	107	0	0	3	
7	1	2	2	2	
8	56	15	15	13	
Mean square pct. error[a]	38.3	91.1	37.2	101.5	

[a] Calculation is based on all 16 data sets using equation (16).

$(\hat{cs} - cs^T)/cs^T$. Column 5 reports the percentage bias estimated by the Taylor's series adjustment factor in (8), i.e., $(\hat{cs} - cs^{corrected})/cs^T$. Likewise, columns 2–4 report the estimated percentage biases from the three bootstrap methods. These biases are computed as the difference between the average cs^* from the bootstrap trials and the point estimate, $\hat{cs}$, and are reported as a percentage of cs^T.

Both the prototype and normal-distribution bootstrap methods in some instances predict very large biases. In general, the bootstrap modified by inequality restrictions is free from these aberrations. In considering these results, note that over a large number of trials the various bootstrap methods must yield an accurate estimate of the bias in their respective simulation worlds. However, use of the bootstrap estimates of bias to "correct" for the bias in a single data sample is another matter. Table 3 suggests that such a correction is probably inappropriate. The table reports the root mean square percentage error (*RMSPE*) from each method of approximating the actual bias from the data sample for each functional form, i.e.,

$$(15)\quad \text{RMSPE} = \sqrt{(1/16)\Sigma(\text{Actual Bias} - \text{Predicted Bias})^2}.$$

These numbers should be compared to treating the $\hat{w}$ as unbiased, i.e., substituting zero into (15) in place of the predicted bias. These numbers are reported in the actual bias column of the *RMSPE* rows in table 3. The modified bootstrap on average predicted the magnitude of bias roughly as well as the default assumption of no bias, but both the prototype and normal-distribution bootstraps performed much worse, supporting the conclusion that bootstrap estimates of bias should probably not be used to adjust point estimates of welfare. Interestingly, the second-order adjustment (column 5) did not fare much better in predicting the magnitude of the bias; the *RMSPE* from the use of $cs^{corrected}$ is only slightly smaller than the *RMSPE* from the zero predicted bias default in the linear model.

Another interesting question regarding the bias of welfare is whether the relative magnitude of the bias differs among different welfare measures or the use of Hicksian rather than Marshallian measures. Table 4 reports t-statistics for tests of whether the bias is significantly different from zero for each of the six welfare measures outlined in table 1.[8] All calculations are based on results from the modified bootstrap.

The bias was significant at the 95% level for the linear model in twenty-six of ninety-six in-

[8] The t-statistics are computed as the ratio of the bias to its standard error, where the standard error is calculated as the standard deviation of the $\hat{w}^*$ from the bootstrap trials divided by $(T)^{1/2}$.

Table 4. *t*-Statistics for the Bias of Welfare Estimates

	Marshallian Consumer Surplus			Hicksian Compensating Variation		
Data Set	Total	Small Price Change	Deadweight Loss	Total	Small Price Change	Deadweight Loss
Linear model						
1	2.98*[a]	0.36	−0.34	2.98*	0.36	−0.34
2	2.21*	−0.63	3.77*	2.22*	−0.63	3.76
3	2.67*	0.79	−0.20	2.67*	0.79	−0.21
4	4.24*	1.71	−3.59*	4.24*	1.71	−3.59*
5	0.67	0.42	0.07	0.69	0.42	0.08
6	1.73	0.75	−0.57	1.73	0.75	−0.57
7	1.33	−0.99	−0.13	1.34	−0.99	−0.14
8	1.53	0.02	0.47	1.54	0.02	0.47
Semilog model						
1	1.15	−1.04	−0.34	1.15	−1.04	−0.34
2	2.66*	−0.08	0.15	2.66*	−0.07	0.13
3	0.77	−1.43	−0.33	0.77	−1.43	−0.33
4	2.63*	−.50	2.07*	2.55*	−0.49	2.05*
5	−0.92	0.48	1.85	−0.92	0.49	1.86
6	0.03	0.83	1.47	0.05	0.83	1.46
7	1.80	1.95	−0.14	1.80	1.95	−0.14
8	2.44*	−0.96	−0.23	2.45*	−0.96	−0.23

[a] Asterisk indicates significance of the bias at the 95% confidence level.

stances, including the large *cs* data sets not reported in table 4. Not surprisingly, the biases were more frequently significant when the error variances were large (18 of the 26 cases) and when the sample sizes were small (19 of the 26 cases).

Data sets 9–16 wherein *cs* was a large fraction of income yielded somewhat more (15/26) of the significant biases than did data sets 1–8. Also notable is that the small price change welfare estimates were less susceptible to bias than were the total surplus or deadweight loss measures. Results for the semilog model were less clear. Across the sixteen data sets, roughly the same number of biases were significant as in the linear model, but just over half of the cases with significant biases also had high variances (17 of 31) or small samples (16 of 31). Once again, the bulk of the significant biases (23/31) came from data sets 9–16.

These results suggest that more and better data are important in reducing estimation bias. However, the number of significant biases discerned for data sets with 100 observations suggests that bias may be an important consideration even for relatively large samples.

The results also indicate that the bias can be either positive or negative with 33/96 instances yielding negative biases for both the linear and semilog models. This result contradicts the conclusion of BHS that Marshallian surplus estimates are biased upward.[9]

The Precision of Welfare Estimates

To examine the relative performance of the alternative bootstrap methods in calculating the precision of welfare estimates, coefficients of variation (CV) were computed for each bootstrap method for the total consumer surplus estimator. The CV is the standard deviation of the bootstrap distribution of the $\hat{w}^*$, divided by the mean, $\bar{w}^*$, of the distribution. Hence, large CVs imply imprecise point estimates and correspond roughly to large confidence intervals. CVs are used rather than confidence intervals because of their more compact representation.

The results, shown in table 5, are strikingly consistent for both the linear and semilog models. The prototype bootstrap and the AFG-T normal bootstrap produce some extremely large CVs that are eliminated when the modified bootstrap is used. For example, the omission of a single bootstrap trial in the first linear model data set

[9] The BHS conclusion was based on comparing the expected value of their expansion of $\hat{cs}$ to $E[cs^T]$ in (5). The discrepancy may be due to the truncation of the Taylor's series or BHS's alternative expansion procedure (see note 2 above).

Table 5. Coefficients of Variation for Total Consumer Surplus from the Alternative Bootstrap Methods

Data Set	Prototype	Modified[a]	Normal	Normal Modified
Linear model				
1	27.98	0.97 (101)	0.91	0.91
2	4.68	1.31 (118)	37.22	3.60
3	0.48	0.48 (106)	0.49	0.69
4	0.84	1.60 (211)	1.97	1.38
5	0.07	0.07 (100)	0.08	0.08
6	0.12	0.12 (100)	0.14	0.14
7	0.15	0.15 (100)	0.16	0.16
8	0.21	0.21 (100)	0.23	0.23
Mean 1–8	4.32	0.61	5.15	0.90
Mean 9–16	0.68	0.20	2.58	0.19
Semilog model				
1	0.16	0.16 (100)	0.15	0.15
2	0.81	0.79 (157)	4.36	4.40
3	0.18	0.18 (100)	0.21	0.21
4	2.46	2.53 (115)	32.11	2.66
5	0.06	0.06 (100)	0.06	0.06
6	0.12	0.12 (100)	0.14	0.14
7	0.12	0.12 (100)	0.12	0.12
8	0.39	0.39 (100)	0.45	0.45
Mean 1–8	0.54	0.54	4.70	1.02
Mean 9–16	4.81	0.26	3.03	0.28

[a] The number of trials used in the modified bootstrap method is reported in parenthesis.

results in a drop in the coefficient of variation from 27.98 to 0.97. Other cases of large improvements in the variance estimates also occur. These improvements are particularly likely to occur when the error variances are large or the number of observations is small. Use of the modified bootstrap induces a six-to-tenfold reduction in the reported variance of $\hat{cs}$. The large variances generated by the unrestricted models undoubtedly reflects estimators without finite moments.

To determine how much of the large variance estimates in the AFG-T normal bootstrap were due to the assumption of normal errors versus the inclusion of bootstrap trials which did not conform to the inequality restrictions in (11) and (12), the experiment was repeated employing both normal errors and the inequality restrictions. As reported in column 4 of table 5, with the exclusion of the aberrant bootstrap trials, sampling from a normal distribution generated results similar to those generated by sampling from the empirical distribution, an average CV of 0.55 from the normal vs. 0.40 from the empirical distribution for the linear model and 0.65 vs. 0.40 for the semilog.

Even in cases where the true errors were uniformly distributed, sampling from a normal distribution did not appear to significantly alter the findings. These results suggest that a normal distribution can be used without introducing substantial errors.

To examine the relative sizes of the coefficients of variation across alternative welfare estimators, table 6 reports CVs from the modified bootstrap for each of the six welfare estimators in table 1. The results are again quite similar for the linear and semilog models and several notable patterns emerge. First, even though the Hicksian measures are computed from estimates of Marshallian demand functions, rely on income coefficients as well as price coefficients and have more complex formulas, the CVs for the Hicksian and Marshallian measures are quite similar. Even data sets 9–16, which produced noticeably different Hicksian and Marshallian measures, yielded similar coefficients of variation.

Second, the total consumer surplus and total compensating variation measures were generally estimated less precisely than the other measures, but the most significant difference was in the precision of estimation of small price change consumer surplus. This result can be explained by noting the portion of each welfare estimate that relies on the precision of the regression estimates. For example, total consumer surplus is the area under the entire demand curve for a given price and, as a result, the measure is likely to be very susceptible to slight changes in the price coefficient. In contrast, the small price change consumer surplus measure contains a large portion which is nonstochastic, the area $(P1 - P0)X1$. The deadweight loss measure is computed by subtracting the nonstochastic component from the small price change consumer surplus, and as such, it shares the total consumer surplus's reliance on the precision of the price coefficient estimate.

Finally, the CVs reported in table 6 provide a rough idea of the magnitude of the confidence intervals around the point estimates of welfare. If plus or minus two standard deviations is used as a rough approximation to 95% confidence intervals, then the average confidence interval around *cs* for both the linear and semilog models is approximately plus or minus 80%, with a range from 12% to 506%. Imprecision is particularly acute for those data sets that are most similar to observed cross-sectional data. For example, the confidence intervals for the first four data sets

Table 6. Coefficients of Variation for the Six Welfare Estimators

	Marshallian Consumer Surplus			Hicksian Compensating Variation		
Data Set	Total	Small Price Change	Deadweight Loss	Total	Small Price Change	Deadweight Loss
Linear model						
1	0.97	0.03	0.37	0.99	0.03	0.38
2	1.31	0.06	0.61	1.34	0.06	0.62
3	0.48	0.04	0.27	0.48	0.04	0.27
4	1.60	0.08	0.42	1.61	0.08	0.42
5	0.07	0.01	0.07	0.07	0.01	0.07
6	0.12	0.01	0.11	0.12	0.01	0.11
7	0.15	0.01	0.14	0.15	0.01	0.14
8	0.21	0.02	0.20	0.21	0.02	0.20
Mean 1–8	0.61	0.03	0.27	0.62	0.03	0.28
Mean 9–16	0.20	0.03	0.21	0.22	0.03	0.24
The semilog model						
1	0.16	0.03	0.13	0.16	0.03	0.13
2	0.79	0.06	0.37	0.80	0.06	0.37
3	0.18	0.05	0.15	0.18	0.05	0.15
4	2.53	0.10	0.72	2.78	0.10	0.72
5	0.06	0.01	0.05	0.06	0.01	0.05
6	0.12	0.02	0.12	0.12	0.02	0.12
7	0.12	0.02	0.11	0.12	0.02	0.11
8	0.39	0.03	0.27	0.39	0.03	0.27
Mean 1–8	0.54	0.04	0.24	0.58	0.04	0.24
Mean 9–16	0.26	0.09	0.22	0.31	0.10	0.23

Note: All estimates are based on the modified bootstrap method.

average about plus or minus 220% and 185% of the *cs* for the linear and semilog models, respectively. The $n = 25$ data sets also generate significantly larger confidence bounds—plus or minus 162% and 192% for the linear and semilog models compared to 84% and 26% for the $n = 100$ data sets. Once again, there appear to be large returns to generating more observations and getting better model fits.

It is also illuminating to compare the standard errors of the $\hat{cs}$ to Willig's bounds on the difference between the Marshallian and Hicksian total welfare estimates (Willig). The ratio of two standard deviations of $\hat{cs}$ to the Willig bounds were computed for each of the sixteen point estimates of *cs* for the semilog model. The average of these ratios across the data sets is about 774. The first 8 data sets, where the difference between the Marshallian and Hicksian measures was very small, yielded, as expected, a much larger average ratio of about 1,520. However, even when considering only the second 8 data sets, where the differences between the Marshallian and Hicksian measures was much larger, the average ratio was 14.05. These results suggest that there are far higher returns from improving the precision of our estimates than from worrying about calculating "exact" measures of welfare. There appears to be a great deal of inexactness when it comes to estimating our "exact" measures.

It is important to emphasize that confidence intervals computed from the bootstrap distribution described earlier will reflect any asymmetries in the small sample distribution of the $\hat{w}$ (Efron 1981b, 1987) and, hence, represent a preferred alternative to crude intervals generated from estimates of the standard error. For example, with the linear model and data set no. 1 the crude 90% confidence interval is $\hat{cs} \in [0, 726.5]$, while the estimated interval derived from the bootstrap distribution with 1,000 trials and Efron's percentile method is $\hat{cs} \in [212.4, 806.1]$. The 90% Bayesian highest posterior density interval (Griffiths) is $\hat{cs} \in [160.4, 585.9]$. Bayesian confidence intervals, it should be noted, are interpreted differently than sampling-theoretic intervals (Griffiths).

A final issue is the appropriate number of bootstrap trials to conduct. A criterion proposed by Kloek and van Dijk for choosing the number of trials in Monte Carlo integration is also pertinent to the bootstrapping scenario. Based on the central limit theorem the mean values from a random sample (e.g., a sample generated from bootstrap trials or Monte Carlo integration) are

approximately normally distributed for sufficiently large n with standard error for the mean equal to the standard error of the sample [see eq. (10)] divided by $n^{1/2}$. Thus, precision of estimation of the mean, say $\bar{w}^*$, can be improved by increasing (in our case) the number of bootstrap trials. From, an estimate of the standard error of the sample and a criterion for precision, it is possible to solve for the approximate number of trials needed to obtain the desired precision.

The precision criterion used here is that a 95% confidence interval around $\bar{w}^*$ should be no wider than $\pm .1\bar{w}^*$, i.e.,

$$\bar{w}^* + 1.96SE[\bar{w}^*] < 1.1\bar{w}^*, \tag{16}$$

where $SE[\bar{w}^*] = (\text{Var}[\hat{w}^*]/n)^{1/2}$ and $\text{Var}[\hat{w}^*]$ is computed from (10). Solving (16) for n provides the estimated minimum number of trials needed to achieve the desired precision.

Applying this criterion to our data sets for the modified bootstrap indicated that 100 successful trials were insufficient for six of the thirty-two data sets: linear #'s 1, 2, and 4 and semilog #'s 2, 4, and 10. These models were re-evaluated using the number of bootstrap trials indicated from solution of (16). The results for bias and coefficients of variation from the expanded trials are reported in table 7. Results from the original 100 successful trials are also provided for comparison. Quite substantial changes in coefficient of variation and bias were found for the linear models, reflecting the imprecision of the results based on 100 trials for these models. Conversely, results did not change much for the three semilog models.

Table 7. Coefficients of Variation and Biases for Total Consumer Surplus from the Modified Bootstrap Using the 10% Accuracy Rule

		Coefficients of Variation		% Biases	
Data Set	Trials[a]	100 Trials[b]	10% Rule	100 Trials[b]	10% Rule
Linear model					
1	361	0.97	0.63	39	22
2	659	1.31	2.38	46	53
4	983	1.60	3.33	44	53
Semilog model					
2	139	0.79	0.66	22	19
4	2459	2.53	2.47	106	93
10	177	0.68	0.60	25	19

[a] This column reports the number of trials satisfying the inequality restrictions undertaken as determined by the accuracy rule discussed in the text.
[b] These coefficients of variation and percentage biases are reproduced from tables 5 and 3, respectively.

Conclusions and Recommendations

Bootstrapping techniques can facilitate applied welfare analysis by enabling researchers to discern whether welfare estimators are likely to exhibit significant bias and to construct standard errors or confidence intervals without appealing to asymptotic properties or making assumptions about underlying error distributions. The simulation results demonstrate the marked improvements possible through imposition of innocuous, theoretically based inequality restrictions on the bootstrap-generated parameters.

Bias in the various welfare estimators was often significant, particularly in the cases most relevant for recreation demand analysts. Although the bootstrap is able to isolate these biases, neither the bootstrap nor the Taylor's series correction were particularly successful on average in predicting the biases from individual data sets. However, bootstraps without the inequality restrictions were much worse at predicting bias. This suggests that the discrepancy between the second-order approximation and bootstrap mean noted by Graham-Tomasi, Adamowicz and Fletcher is probably due to the unmodified bootstrap's poor performance rather than the truncation bias of the second-order approximation, as G-TAF conclude.

The results also demonstrate that welfare measures can be estimated quite imprecisely, especially for data samples typical of applied recreation analysis. Standard errors for the total Hicksian and Marshallian measures in these cases were, on average, of the same magnitude as the point estimate, and the associated confidence intervals were much larger than either the Willig bounds or the biases.

The coefficients of variation and bias from the modified bootstrap for the linear and semilog models were very similar. This suggests that the effect of functional form on variance and bias may be alleviated by imposing inequality constraints. Thus, choice of functional form (Kling) can be based on other factors, such as goodness of fit, rather than concerns about alternative functions' tendencies to generate welfare estimators with inherently larger biases or variances.

Finally, and perhaps most instructively, the simulation results indicate that both the biases and the variances of welfare estimators can be

reduced, sometimes dramatically, with more data and better fits of the models. There may be higher returns to collecting more and better data than from worrying about theoretical discrepancies between various measures.

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Signals or Noise? Explaining the Variation in Recreation Benefit Estimates

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This paper uses meta analysis to summarize the benefit estimates derived from travel cost recreation demand models. After reviewing approximately 200 published and unpublished studies prepared from 1970 to 1986, 77 were found to report either consumer surplus estimates or sufficient information to derive them. Using these estimates of the consumer surplus per unit of use from each study, it was possible to evaluate the influence of variables describing the site characteristics, the activities undertaken at each site, the behavioral assumptions, and the specification decisions. The findings provide clear support for using econometric methods to summarize results from diverse empirical studies. They highlight the important research issues in model development and offer a consistency check to the procedures used in benefit transfer analyses for policy evaluations.

Key words: consumer surplus, meta analysis, recreation demand.

This paper proposes a new method for taking stock of current estimates of the benefits users derive from environmental resources: an econometric review of the literature. This approach is applied to empirical studies using the travel cost method to estimate the demand for specific recreation sites, but it has general relevance for gauging what has been learned by empirical research in many other areas of economics.[1]

The research landscape for benefit estimatio has changed dramatically since Freeman wrot his influential overview of the field in 197S Freeman's book responded to a gap in the li erature on benefit estimation. There had bee "substantial research effort devoted to deve oping a rigorous and unambiguous definition an measure of changes in welfare at the theoretic level . . ." but "relatively little concern fc translating the theoretical concepts and defin tions into usable, operational empirical tecl niques" (Freeman, p. 15). This situation ha changed, especially in the United States. Of th 77 travel cost recreation demand studies ana lyzed in this paper, 61 were prepared since 198C Mitchell and Carson identified over 120 contir gent valuation studies, most completed afte 1980. Of the 35 hedonic property value studie considering the effects of air pollution, 30 be came available after 1980. Certainly the ir creased role given to benefit-cost analyses fc evaluating environmental policies in Executiv Order 12291 (issued in February 1981) has cor tributed to the dramatic expansion in this litel ature [Smith 1984 and Office of Policy Analy sis, U.S. Environmental Protection Agenc (EPA) for evaluations]. Nonetheless, the avai able benefit estimates fall short of what is neede for an increasing array of policy related activi

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A large number of individuals contributed to this effort by providing the source materials for both published and unpublished papers. Since the authors wrote to all the individuals whom they could identify as active researchers in recreation economics, and all chairs of Departments of Agricultural Economics and of Economics, they cannot identify them individually. Thanks go to Michael Hanemann for calling the authors' attention to the meta-analysis literature outside economics and to John Braden, Jerry Carlson, Peter Caulkins, Bill Desvousges, Ted McConnell, and three anonymous referees for exceptionally careful and constructive comments on earlier drafts of this paper.

[1] Hedges and Olkin credit Glass with the first use of meta-analysis in educational and psychological research. There are important differences in the use of these methods for applications in these disciplines, as well as for medical research, in comparison with economics. All of the former have involved controlled experiments, where the statistical analysis can be treated as aggregating independent observations from each study's sample of experimental findings (see Cordray).

ties (Ward and Loomis; Naughton, Parsons, and Desvousges).

Indeed, the practice of adjusting the results from one or more existing studies for a specific type of environmental resource and using them to value changes in another resource is commonplace in policy analysis. Labeled "Benefits Transfer," this process usually involves: (*a*) adjusting or transferring an estimated model (or set of per unit benefit estimates) from the situation where it was developed to the new application; and (*b*) developing an aggregate estimate for the relevant population from per unit estimates and other assumptions. While judgment is important in both steps, it has been the principal basis for the first step. Many of the published sources used for benefit estimates in policy analysis were not designed to provide measures of the benefits for a change in the quantity or quality of a resource. Rather, they were developed to introduce a new model, test a hypothesis, evaluate the implications of specific assumptions, or illustrate a new estimator. Consequently, they must be adapted for benefit measurement. The nature of these modifications depends upon both the benefit estimation task and the information reported in the original sources.

Our findings show a systematic relationship between the estimates and the features of the empirical models. Both the type of recreation site involved and the assumptions made in developing the empirical models are important in explaining the results. The variables used to describe models are classified according to whether they attempted to reflect specific theoretical issues associated with individuals' recreation decisions or analysts' judgments needed to estimate a model (e.g., selecting a functional form for the demand model or making assumptions to compensate for inadequate data). Ideally, the latter variables would not be important determinants of the variation in benefit estimates, but the findings here suggest that they are.

The specific factors found to be significant determinants of the real consumer surplus per unit of use have direct implications for research on households' recreation decision making, for further uses of the travel cost demand model, and for the practices used in transferring benefit estimates derived from this class of models to new applications. These implications are explored in the last section of the paper, after developing the background, describing the data set and methodology, and presenting the results.

Statistical Methods for Synthesizing Research

The use of statistical methods to develop a research synthesis has a long history. Termed meta analysis, most of these applications have involved controlled experiments in psychology, education, or the health sciences. They have focused on consistently aggregating the results from different controlled experiments. The methods are motivated by the desire to avoid the subjective nature of most research reviews. Conventional reviews of empirical literature usually summarize the presence or absence of statistically significant effects and, in some cases, compare the size of estimated effects. While many of these studies have attempted to draw some bottom line conclusions about what is known (as Light and Pillemer observed), these types of appraisals often violate simple statistical principles in distilling an admittedly complex array of work. Moreover, to develop this type of summary, the reviewer usually must adapt the multiple (and often complex) features of the studies to fit some comparable format in order to propose a consensus judgment.

Because empirical research in economics is usually not based on experimental data and may well report multiple models applied to a single data base, our proposed methodology is different from that used in most meta analyses (Cordray). It must reflect both the modeling judgments (made because controlled experiments are usually impossible) and the interdependent panel nature of any sample of research results. Fortunately, both issues can be addressed with existing econometric methods.

Moreover, the rationale for using an econometric framework for synthesizing the benefit estimates for environmental resources is more general. Empirical models are combinations of prior theory and the analyst's judgment. That judgment combines at least four elements: the problem or issue the empirical model seeks to address (e.g., test a hypothesis or estimate a specific parameter or quantity); the economic theory of behavior relevant to the problem; the data available to estimate the model; and the learning that accompanies evaluating the joint effects of functional specification, variable construction, and the results from prior model formulations in relationship to the existing literature.

The last of these, sometimes referred to as specification searches or data mining, has been

widely criticized in the recent econometric literature. However, by viewing models as approximations, there is further motivation for using statistical summaries of the results from existing models to evaluate the importance of such compromises for the findings.

A Simple Model of Recreation Demand

The travel cost recreation demand model can be described as a derived demand for a recreation site that contributes to each individual's production of a recreational activity providing utility (Deyak and Smith or Bockstael and McConnell 1981, 1983). This framework helps to describe the components of modeling decisions that may explain the variation in consumer surplus estimates across travel cost demand studies.

Consider a simple utility function specified in terms of the activities a person wants to consume, S_i's, as in equation (1).

$$(1) \qquad U = U(S_1, S_2, \ldots, S_k).$$

Each S_i is assumed to be produced by combining market goods, x_{ji}'s; time, t_i; and nonmarketed commodities, y_{ki}'s, as in equation (2). Of course, some activities may not use some inputs.

$$(2) \qquad S_i = f_i(x_{1i}, \ldots, x_{ni}, t_i, y_{1i}, \ldots, y_{mi}),$$

where $x_{1i}, \ldots, x_{ni}$ are the amounts of the n marketed commodities, t_i is the amount of an individual's time, and $y_{1i}, \ldots, y_{mi}$ are the amounts of the nonmarketed commodities, all used in the production of S_i. In recreation applications, these are the services of the recreation sites used by each individual. Budget and time constraints must be added to formally derive the implications of this model for travel cost demand models.

The specification of these demand functions will follow from the assumptions incorporated in these constraints. For example, if the analyst assumes the length of time spent on site during each trip is constant, site entrance fees are negligible, and any free time could be spent working at a predefined wage, then the quantity demanded for a site can be readily measured by the number of trips to the site (v). Moreover, the implicit price of a trip becomes the sum of vehicle-related travel costs and the opportunity costs of travel time (evaluated at the wage rate). This is represented as P.

If the amount of time each individual has available for work or leisure is fixed for the p riod of analysis and known, Becker's full i come (I) becomes the relevant income measu in this demand function. Substitute sites' trav costs (i.e., vehicle and time) and the prices other commodities relevant to these decisions ca also be justified as arguments (P_s). Most ec nomic models assume individuals share con mon behavioral objectives and usually mainta that heterogeneity in people's responses aris from taste differences. These effects are repr sented with demographic characteristics (d Thus, at a general level, the site demand fun tion would be given by equation (3)

$$(3) \qquad v = g(P, P_s, I, d).$$

In most applications, features of this function c transformations of it are the focus of the ana ysis.

In developing an econometric review of thes studies, the feature(s) of $g(.)$ that will be the fc cus of the summary must be identified. If a studies adopted a common specification for th demand function, one might use specific paran eters and the meta-analysis would be similar t the varying parameter models used to estimat the effects of quality changes on site demanc (Vaughan and Russell or Smith and Desvousge [1985]). Even without a common form, th marginal effects or the elasticities could be th focus of an econometric summary.

To evaluate which measure might be best, w need a model of the process of developing ir dividual models (Hendry). However, in pract cal terms, statistical summaries depend on th use of the results and the amount of informatio reported with each study.

Because an important objective of this revie is to evaluate the properties of benefit estimate derived from these models, we selected the cor sumer surplus (CS) per unit of use (v). This se lection attempts to adjust for the accessibility c recreation sites to users by averaging the cor sumer surplus over the use relevant to the tim horizon of the model. It is also consistent wit evaluating the transferability of existing mode because the focus of these efforts is often to de velop unit benefit estimates that can be applie to new situations. Unfortunately, convention theory does not offer clear guidance on the ex pected properties of this measure. This is easil seen by describing it in terms of the deman function in (3). CS/v can be defined formall by

$$CS/v = L(P_o, P_c, P_s, I, d) = \int_{P_o}^{P_c} [g(p, P_s, I, d)/g(P_o, P_s, I, d)]dp, \tag{4}$$

where P_o is the current price and P_c is the choke price.

The estimates of consumer surplus from the literature are generally for specific sites or derived from regional travel cost models hypothesized to describe sets of sites in the same geographic region. To estimate CS/v requires some specification of the variables hypothesized to influence $L(.)$. In many cases, the estimates were provided in the studies. Where they were not provided, information reported in each study was used to estimate the consumer surplus per unit that was representative for a typical user of the site. Developing a model for how CS/v would vary across studies requires recognition that it may vary for different types of recreation sites because their demand functions would be different. Depending on the role of other variables influencing these demands, the type of site could also be a factor affecting $L(.)$. Equally important, different studies have adopted different assumptions about the household's choice problem. These differences alter how the own price of a site or of substitutes is measured. A priori we do not know which characterization is best. Because these maintained assumptions serve as prior restrictions in the estimated models, the estimates of CS/v likely will be affected. Finally, the data available will often constrain the modeling features and must be reflected as well.

For travel cost demand studies, these factors can be classified into five types of decisions: (*a*) specifying the types of recreation sites; (*b*) defining a recreation site, its usage, and the site quality; (*c*) modeling the opportunity cost of time; (*d*) describing the role of substitute sites in producing the recreation service flows; (*e*) linking the specification of the demand model to an underlying behavioral model.

Types of recreation sites. The household production framework recognizes site demand as a derived demand. Thus, both the types of site services and the types of activities undertaken must be considered. In an early attempt to classify recreation sites, Clawson and Knetsch identified three categories—user-oriented, intermediate, and resource-based. User-oriented sites included city and county parks, golf courses, tennis courts, swimming pools, playgrounds, etc. Intermediate sites were federal and state reservoirs and parks that provide hiking, camping, fishing, boating, and hunting. Resource-based sites had special physical characteristics and were mainly national sites. Their unique attributes cause recreationists to perceive recreation at these sites as distinctive from the same activities undertaken elsewhere.

The Clawson/Knetsch perspective is adopted here, but cursory site descriptions in many of the studies force our categorization to be crude. A site is allowed to belong to more than one category. A site with a lake simultaneously may be a national park with wilderness significance. To reflect the differences in users' activities at each site, we identified from each study's description the primary activities a site supported and used this information to specify qualitative variables for each study's demand function.

These activity variables may also capture the influence of the model screening associated with pretesting. An analyst's evaluation of a model can involve comparing its consumer surplus estimate with results from the past literature to gauge the model's plausibility. Because most of the commonly accepted estimates of per-unit values have been for recreational activities rather than recreation sites, variables describing activities undertaken at sites may be proxies for the informal screening rules used in model selection. Examples of the activity-based sources for recreation value estimates include the Water Resource Council estimates of unit day values, the Sorg-Loomis review for the Forest Service RPA process, and (most recently) the Walsh, Johnson, and McKean update of the Sorg-Loomis summary of the benefits per day of specified recreational activities.

Identifying a recreation site and measuring its use. The early travel cost literature treated sites as well-defined entities. However, site definition can be hampered by three factors: (*a*) large resources, such as national forests or estuaries, where the areas do not have uniform characteristics and there are multiple entry points, but no obvious basis for defining subsets of the area for separate analysis; (*b*) large numbers of similar resources in close proximity to one another, such as lakes or ski sites, where each lake is a close substitute for the others and is about the same distance from the bulk of potential users; and (*c*) data constraints that limit our ability to isolate

the resource providing the service, such as deep-sea fishing.

In response to these difficulties, several studies pooled data across sites, arguing that their parameters were approximately constant (Sutherland [1982a]) or that site characteristics could be explicitly incorporated into the model (Vaughan and Russell, Smith and Desvousges 1985).

The variables used to measure an individual's quantity demanded of a site's services are also important in distinguishing the available models. This specification is another example of a decision where an a priori selection of a "best" measure is not always apparent. In particular, price measurement must be coordinated with quantity measurement. Some quantity measures can imply nonlinearities in the individual's budget constraint. Defining use typically involves two considerations—the treatment of on-site time per trip and the time horizon for decision making. From the perspective of a season, if y_{kl} in equation (2) represents the use of recreation site k, we might ask if site use is measured as total time at the site or if trips and time-on-site per trip should be distinguished. For many activities, the "production process" for a day of recreation is comparable to what would be involved in a longer stay. Longer trips allow more of the activity (service flow) to be produced. For other activities, this assumption is not reasonable. Price per unit of use will have both fixed and variable components if use-per-trip is not held constant. Thus, the measure selected for quantity will be important to the existence of a conventional Marshallian demand function.[2] Based on these arguments, we define variables that describe the measurement of use (i.e., days versus trips) and the treatment of on-site-time in the models.

Opportunity cost of time. There are a variety of potential specifications for the constraints to household utility maximization—technology, income, and time constraints. The full income concept, following Becker's original usage, links time and monetary constraints by defining income in terms of earnings and other sources of income. Time is assumed to be freely substituted in any use, so all uses of time have th same opportunity costs (the wage rate). An a ternative specification allows for different op portunity costs, using the wage rates for par time work (Bockstael, Strand, and Hanemann Yet another possibility specifies different tim constraints and maintains that not all types o time can be substituted (Smith, Desvousges, an McGivney).

With detailed information on the time cor straints, wage rates, and job opportunities fo individuals, these models could be tested. Ur fortunately, because there are data limitation the literature offers a selection of approxima tions. Because wage rates are often unknow they must be estimated.

The time horizon for decision making is es pecially relevant to comparisons of recreatio models developed using a random utility (RUM framework (e.g., Bockstael, Hanemann, an Kling or Morey, Rowe, and Shaw). RUM mode seek to explain decisions on single trips, as each decision was independent of prior dec sions. Opportunity costs then must be treate differently because the compressed decision ho rizon may limit the choice set.

Measures of site usage and individual time a location decisions are exceptionally limited. Thu analysts have usually proposed informal rule such as maintaining that opportunity costs ar between one-fourth and one-half the level of th wage rate (Cesario and Knetsch). The prese analysis employs variables that describe how pa studies measured the wage rate and how the described the opportunity cost of travel time.

The treatment of substitute sites. There is li tle to debate about the relevance of substitut prices for modeling the demand for any com modity, including recreation sites. As a rul however, microlevel recreation surveys includ information on the respondents' judgments abo their "next best alternative" without determi ing what sites are actually available and how po tential users perceive alternative sites. Furthe more, collinearity between price measures ca yield the appearance of a small role for subst tute prices (Rosenthal 1985, 1987). For the mo part, past treatments of substitutes can be groupe into three alternatives: (*a*) excluding substitute (the majority of the work); (*b*) formulating a bitrary indexes of existence of substitutes usin a diverse array of specifications (each with littl connection to micro theory); and (*c*) includin a selection of substitute prices. These altern

[2] This problem is analogous to the issues raised in modeling the demand for electricity in the presence of declining block rates (see Taylor for an early discussion) or in the more recent analyses of hedonic models' ability to recover estimates of the willingness-to-pay functions for nonmarketed resources. See Bartik and Smith.

tives are captured in variables describing the treatment of substitutes for the present analysis.

The behavioral framework and the empirical model. Any model specification introduces implicit restrictions that affect how any sample of actual choices is described. Economists working with recreation demand modeling are beginning to question how these implicit restrictions should be selected. For example, Kealy and Bishop; Bockstael, Hanemann, and Strand; and other authors argue that these specifications should follow from a well-defined behavioral model, based on a specific functional specification for either the direct or the indirect utility function. A contrasting view might suggest that, because information is incomplete, starting with a "reduced-form" approximation is just as effective as using a complete behavioral description.

An examination of existing studies cannot answer this question, because the truth is not known. Nonetheless, an evaluation of the influence of the demand specification on the consumer surplus estimates indicates whether an answer is important. To this end, the variables used to describe each set of estimates were grouped into two classes—one reflecting economically plausible maintained hypotheses and a second reflecting ad hoc adjustments where either the economic theory does not provide guidance or limitations in the available data require assumptions. By testing whether the second set of variables accounts for a significant share of the variation in the consumer surplus estimates across studies, the importance of ad hoc modeling decisions can be gauged.

Data and Empirical Model

The analysis is based on a review of published articles in a wide array of journals that included travel cost demand models, government reports, and unpublished papers, as well as masters' and Ph.D. theses from 1970–86. The studies were identified by surveying all issues of the relevant journals; by contacting economists who have developed travel cost demand models, government agencies (e.g., the Fish and Wildlife Service, Office of Policy Analysis in the Department of Interior, Forest Service Regional Offices, and others) and the chairpersons of departments of agricultural economics and economics for unpublished papers and graduate students' masters and Ph.D. essays; and by reviewing the University of Michigan microfilm listings for the abstracted Ph.D. dissertations in resource economics. To the extent possible, double entries for unpublished Ph.D. theses, and subsequently published articles were avoided.

Approximately 200 studies were reviewed to determine if they had empirical estimates for travel cost recreation demand models and provided sufficient information to estimate the Marshallian consumer surplus per unit of use. The results described here relate to 77 studies that either reported benefit estimates or provided sufficient information to derive them. The appendix lists the studies and the range of consumer surplus estimates in real terms for those with sufficient information to be included in the final empirical models (columns 6, 7, and 8 in table 2). Using all 77 studies, there would be 734 observations for our analysis. However, as discussed below, the information is not complete on all variables. Moreover, several studies are responsible for multiple observations because they reported alternative results due to different functional forms, maintained assumptions, estimators, or definition for the recreation sites. Consequently, the sample resembles a panel data set, and this feature must be reflected in the analysis.

The basic empirical hypothesis is that the variation in benefit estimates arises from differences in the theory underlying these demand analyses together with practical implementation issues. The variables used to explain variation in the estimates of benefits can be classified according to (*a*) the assumptions inherent in the behavioral model underlying the travel cost framework, including the measures for quantity and own price and the treatment of substitutes (designated here by a vector of variables, X_B); (*b*) the specifications of the estimated demand function (designated by a vector of variables, X_D); and (*c*) the econometric estimator (designated by a vector, X_E). Equation (4) defined consumer surplus per unit of use for a given recreation site. As observed earlier, in formulating hypotheses concerning the effects of each class of variables on variations in the estimates of CS/v, it is important to recognize that the features of each recreation site (X_S) and the recreational activities undertaken (X_A) should influence the true value for consumer surplus per unit. Moreover, differences in the assumptions made for the variables in $L(.)$ will contribute to variations in estimates of CS/v. If differences in these specifications for other economic and demographic variables are not important, then the true surplus

might be hypothesized as a function of variations in X_S and X_A as in equation (5) where the subscript i is used to designate each estimate.

$$(5) \qquad (CS/v)_{Ti} = \alpha_0 + \alpha_s X_{Si} + \alpha_A X_{Ai}.$$

Only the semilog demand specification satisfies this condition. If b designates the absolute value of the price coefficient, then $1/b$ is often used as a measure of the Marshallian consumer surplus per unit of use and would be the estimator of CS/v. The measure of use would depend on the definition of the quantity variable used for the model.[3]

If economic and demographic characteristics of the samples are greatly different for the same type of site across studies, then we would expect α_0 to vary with those differences. $(CS/v)_T$ is measured per unit of use to reflect differences in the conditions of access across studies. This formulation implicitly assumes the average consumer surplus per unit of use should be comparable (for the same types of resources, uses, and individuals) when the conditions of access are comparable.

Estimates of $(CS/v)_T$ will be functions of demand parameter estimates, as well as the variables determining individual demand. Because these estimated parameters are functions of the true values of the parameters, it is reasonable to hypothesize that the estimated consumer surplus per unit of use, $(CS/v)_E$ is some function of $(CS/v)_T$. Our proposal for summarizing empirical work implicitly maintains that more factors are involved—the variables describing each study's maintained behavioral assumptions (X_B), as well as each analyst's judgments (X_D and X_E). Equation (6) hypothesizes that these effects are additive influences to the true value and therefore would be reflected in the bias in any estimator for $(CS/v)_T$.

$$(6) \qquad (CS/v)_{Ei} = \beta(CS/v)_{Ti} + \gamma Z_i + \epsilon_i,$$

where Z_i is a vector of variables describing modeling decisions (i.e., $Z_i = (X_{Bi} \quad X_{Di} \quad X_{Ei})$, with γ a conformably dimensioned vector of parameters), and ϵ_i is a stochastic error.

The simple linear form of equation (6) has no intercept because we hypothesize that there is no fixed bias, independent of the modeling assumptions, in the estimates for consumer surplus per unit. The fixed bias will depend on the model used. Of course, variables may well t omitted, but these are more likely reflected i the error term, ϵ_i, because they likely vary wi each study. Substituting (5) into (6) gives tł basic form of the estimating model

$$(CS/v)_{Ei} = \beta\alpha_O + \beta\alpha_s X_{Si} + \beta\alpha_A X_{Ai} + \gamma Z_i + \epsilon$$

Under ideal conditions β would be unity.

An important element of an attempt to explai the results of applied economic research is tł development of hypotheses for the componen of Z_i. Following Hendry, if any economic mod is a strategy determined by the problem at har and the information available, then some el ments of modeling decisions (such as the trea ment of substitutes or the specification of tł opportunity cost of time) should play a role i the true demand function for a recreation sit But it is impossible to specify which assumptic is correct. Moreover, this judgment may deper on the application. Thus, studies that fail to re ognize these factors can be distinguished fro those that do, but a best strategy cannot be d termined for each case.

In applications of meta analysis in other di ciplines, an evaluation (by the meta analyst) (the experimental design, measurement proc dures, and controls is used to score the likel quality of each study's results to develop quali weights. These weights are applied to the resul from each study as part of the development (the statistical aggregate. This approach is not use here for two reasons. First, and most importan the correct treatment of the modeling judgmen inherent in most empirical economic research f a statistical summary depends on whether the affect the bias or variance in the estimate Weighting implicitly assumes that the estimate based on incorrect modeling judgments remai unbiased but simply have less information content (i.e., have higher variance). This ma be appropriate for summarizing controlled e periments, but it is less clear for economic a plications.

Second, modeling decisions may reflect se eral specific maintained hypotheses in each stud so developing weights would require scaling tł quality of these decisions. This is not possib given our current knowledge about how peop make recreation decisions.

With this background, we can distinguis variables that are largely associated with dat based decisions where little guidance is avai able in economic theory (those in X_D and X from those that are based on theory (X_B). As note

[3] While this estimator for (CS/v) has been commonly used in the literature, without checks to screen for negative values, it will not have finite moments (see Smith 1989).

earlier, from the perspective of transferring estimates from one applicaton to a new resource involved in a policy decision, it would be desirable if the data-based decisions played a small role in explaining variations in the CS/v estimates.

Results

Table 1 defines the specific variables used in explaining estimates of the consumer surplus per unit of use. $(CS/v)_{Ei}$ is measured by the real (constant dollar) consumer surplus per unit of use. Most of the variables are qualitative. Because $(CS/v)_{Ei}$ is derived from empirical models based on quite different data sets and estimation methods, it is reasonable to expect heteroskedasticity. Indeed, as Bockstael and Strand observed, it should be possible to estimate the variances in these estimates for the consumer surplus. However, two problems arise in implementing their suggestions with each of the demand specifications used in this study. First, the information routinely reported in travel cost demand studies is generally not sufficient to construct approximate estimates of the CS/v variances. Second, recent studies indicate that the approximations used in constructing these estimates can themselves be subject to important errors (Smith 1990, Kling and Sexton).

The panel nature of our data introduces other sources of nonspherical errors. For example, a simple random effects model would imply autocorrelation because results from different models reported within the same study share a common error. One could distinguish (in specifying the error process) whether the different estimates reported for each study reflected different modeling assumptions for the same site, the same basic model applied to different recreation sites, or some combination of these effects (as might be present in the regional travel cost models).

An estimator that accounts for the composite effects of all of these factors would require im-

Table 1. Description of Variables for Analysis

Name	Mean	Definition of Variables
(CS/v)	25.24	Marshallian consumer surplus estimated per unit of use, as measured by each study (i.e., per day or per trip) deflated by consumer price index (base = 1967).
Surtype	.86	Qualitative variable for measure of site use = 1 for per trip measure, 0 for per day measure.
Type of Recreation Activities		Water-based recreation (swimming, boating, fishing), hunting, wilderness hiking, and developed camping were identified as the primary activities. The first three are introduced as qualitative variables with developed camping as the omitted category.
Type of Recreation Site		Lake, river, coastal area and wetlands, forest or mountain area, developed or state park, national park with or without wilderness significance are the designations. Coastal area and wetlands was the omitted category. Variables are unity if satisfying designation, zero otherwise.
Substitute Price	.29	Qualitative variable = 1 if substitute price term was included in the demand specification, 0 otherwise.
Opportunity Cost type #1	.24	Qualitative variable for the measure used to estimate opportunity cost of travel time = 1 if an average wage rate was used.
Opportunity Cost type #2	.32	Qualitative variable for the second type of opportunity costs of travel time measure, = 1 for use of income per hour; the omitted category was the use of individual-specific wage rates.
Fraction of wage	.37	Fraction of wage rate used to estimate opportunity cost of travel time.
Specific Site	.24	Qualitative variable for use of a state or regional travel cost model describing demand for a set of sites = 1, 0 otherwise.
Demand Specifications		Linear, log linear and semilog (dep) are qualitative variables describing the specification of functional form for demand (semilog in logs of independent variables was the omitted category).
Year		The year of the data used in each study.
Estimators Used[a]		OLS, GLS, and ML-TRUNC are qualitative variables for estimators used, omitted cateogires correspond to estimators with limited representation in studies—the simultaneous equation estimators.

[a] ML-TRUNC refers to maximum likelihood estimators adjusting for truncation and tobit estimators. GLS includes both single equation generalized least squares and seemingly unrelated regressions.

posing considerable prior information to estimate the relevant variances and covariances for the estimates of $(CS/v)_{Ei}$ across studies. To avoid imposition of largely arbitrary assumptions, an alternative strategy is used. This involves estimating equation (7) with ordinary least squares (OLS) but reporting the Newey-West version of the White consistent covariance estimator for OLS in the presence of heteroskedasticity and generalized autocorrelation.[4] The results in table 2 indicate that the basic conclusions are largely unaffected by the standard errors used in significance tests for individual variables.

Table 2 reports the results for several models. The numbers in parentheses are the *t*-ratios calculated with the OLS standard errors, while those in brackets are the *t*-ratios using the standard errors from the adapted White consistent covariance matrix. The eight models illustrate different aspects of our summary. The first three ignore the role of recreation activities and focus exclusively on either assumption variables [column (1)], or site type variables [column (2)], or both [column (3)]. Column (4) expands the analysis in column (2) to include the primary recreational activities supported by the site. Columns (3) and (5) treat the definition of site type and primary recreational activities as alternative proxies for the same effects, and include the other variables describing the modeling strategies. Column (6) reports the most detailed model, and (7) reports the same model omitting only th variables reflecting data-based judgments. Th last column offers an alternative to (6), deletin the variable for the year of the study's data.

The variable "year" was included to invest gate whether recreational resources were grov ing more or less scarce over time.[5] Howeve this variable may also represent changes in th types of data, estimators, and methodologic advances over the time period of our review The influence of these factors as systematic re finements in methodology over time cannot b distinguished from a scarcity-related trend in th availability of recreation resources relative t demand. This trend effect on the relative valu is what one would like to evaluate for the sca city issue. The equations of the final model ir clude all types of effects, with and without th year variable. However, column (8) is probabl a better overall description [despite the statist cal significance of the year variable in the mod reported in column (6)] because of the consi tency in the parameter estimates with other le complete models and the consistent pattern c change in the variables describing each study characteristics when year is included.

The first five columns in table 2 explore th effects of missing values of particular classes c explanatory variables. While gaps and incor sistencies in reporting practices can be seriou obstacles to a meta-analysis of existing empir cal studies, the estimated effects of the variable

[4] A lag of eleven periods was used in implementing the Newey-West version of White's estimator.

[5] This analysis was suggested by an anonymous referee.

Table 2. Determinants of Real Consumer Surplus per Unit of Use

	Models							
Independent Variables	1	2	3	4	5	6	7	8
Intercept	20.30	27.03	18.75	23.48	−.30	5174.24	4904.00	−25.2
	(6.19)[a]	(3.68)	(0.58)	(1.57)	(−.01)	(3.95)	(3.75)	(−0.5
	[3.92]	[3.64]	[1.04]	[3.71]	[−0.01]	[3.39]	[3.52]	[−1.74
Surtype	−9.97	15.38	19.88		1.03	28.75	16.94	19.1
	(−2.72)	(2.97)	(3.74)		(0.23)	(4.84)	(2.78)	(3.4
	[−1.36]	[2.34]	[3.55]		[0.12]	[4.71]	[2.05]	[3.1
(X_A) Type of recreation								
Water-based activities				14.50	24.50	24.43	−9.07	45.3
				(0.83)	(1.97)	(0.78)	(−0.26)	(1.4
				[1.08]	[2.72]	[1.95]	[−0.96]	[4.01
Hunting				17.35	20.02	−2.33	−1.10	13.7
				(1.33)	(1.53)	(−0.18)	(−0.08)	(1.0
				[4.23]	[1.63]	[−0.26]	[−0.14]	[1.4
Wilderness				−12.10	10.92	−26.57	−17.52	.6
				(−0.66)	(0.76)	(−1.47)	(−0.91)	(0.0
				[−2.49]	[0.62]	[−1.95]	[−1.47]	[0.0

Table 2. Continued

Independent Variables	Models 1	2	3	4	5	6	7	8
(X_S) Type of site								
Lake		−18.69	−20.32	−17.47		−22.16	−13.21	−21.19
		(−3.24)	(−3.52)	(−3.12)		(−3.88)	(−2.42)	(−3.65)
		[−2.36]	[−2.48]	[−2.28]		[−2.57]	[−1.60]	[−2.55]
River		−14.29	−19.03	−12.19		−16.44	3.23	−19.80
		(−2.99)	(−2.19)	(−2.57)		(−1.91)	(0.44)	(−2.27)
		[−1.95]	[−1.75]	[−1.86]		[−1.60]	[0.32]	[−1.80]
Forest		−18.45	−25.99	−15.37		−1.36	−20.74	6.84
		(−2.36)	(−3.01)	(−1.31)		(−0.05)	(−0.64)	(0.23)
		[−1.93]	[−2.49]	[−2.53]		[−0.16]	[−2.25]	[0.82]
State park		24.95	22.37	14.10		28.39	24.46	22.18
		(3.47)	(3.44)	(2.40)		(4.28)	(3.44)	(3.37)
		[3.27]	[3.19]	[1.64]		[3.30]	[3.07]	[3.20]
National park		.56	−3.77	30.71		49.37	−5.43	41.13
		(0.04)	(−0.23)	(2.16)		(1.33)	(−0.14)	(1.09)
		[0.08]	[−0.13]	[2.51]		[1.58]	[−0.25]	[1.24]
(X_B) Model assumption								
Substitute price	−18.73		−13.71		−23.80	−11.42	−18.58	−14.39
	(−3.27)		(−2.12)		(−3.76)	(−1.82)	(−3.00)	(−2.26)
	[−4.58]		[−1.80]		[−3.18]	[−1.43]	[−4.10]	[−1.80]
Opportunity cost type #1	−14.97		−16.49		−21.68	−6.03	8.03	−14.28
	(−2.10)		(−2.11)		(−2.94)	(−0.73)	(0.97)	(−1.75)
	[−2.09]		[−2.48]		[−2.72]	[−0.71]	[0.95]	[−1.98]
Opportunity cost type #2	3.95		−15.86		−13.59	−10.97	5.84	−15.89
	(1.02)		(−3.30)		(−2.75)	(−2.22)	(1.39)	(−3.26)
	[0.45]		[−2.87]		[−1.93]	[−1.90]	[0.71]	[−2.80]
Fraction of wage	37.24		48.59		55.88	45.10	27.02	48.59
	(8.56)		(9.76)		(11.41)	(9.09)	(6.01)	(9.76)
	[3.83]		[6.94]		[7.33]	[6.70]	[2.54]	[6.91]
Specific site/regional TC model	22.23		24.21		21.75	16.49		23.54
	(4.10)		(3.85)		(3.54)	(2.55)		(3.71)
	[3.35]		[2.77]		[2.08]	[1.62]		[2.64]
(X_D) model specification								
Linear			−2.87		12.99	−15.33		−2.94
			(−0.27)		(1.19)	(−1.37)		(−0.27)
			[−0.31]		[1.10]	[−1.41]		[−0.29]
Loglinear			23.37		28.57	15.61		24.65
			(2.37)		(2.67)	(1.37)		(2.36)
			[2.88]		[2.05]	[1.59]		[2.68]
Semilog (Dep)			16.89		15.97	9.29		18.61
			(1.86)		(1.62)	(0.97)		(1.96)
			[2.97]		[2.07]	[1.74]		[2.86]
(X_E) estimator								
OLS			−14.45		−24.20	−28.96		−16.21
			(−0.48)		(−0.76)	(−0.96)		(−0.53)
			[−0.84]		[−1.39]	[−1.39]		[−0.92]
GLS			−8.58		−24.77	−21.88		−8.58
			(−0.28)		(−0.78)	(−0.73)		(−0.28)
			[−0.54]		[−1.53]	[−1.13]		[−0.53]
ML-Trunc			−67.38		−77.35	−85.06		−68.98
			(−2.15)		(−2.38)	(−2.74)		(−2.20)
			[−3.43]		[−3.65]	[−3.63]		[−3.46]
Year						−2.61	−2.47	
						(−3.98)	(−3.74)	
						[−3.63]	[−3.52]	
R^2	.25	.15	.42	.15	.36	.45	.30	.43
n	399	399	399	405	405	399	399	399

[a] The numbers in parentheses below the estimated parameters are the ratios of the coefficients to their estimated standard errors. The numbers in brackets use the Newey-West variant of the White consistent covariance estimates for the standard errors in calculating these ratios.

describing the modeling strategies are quite stable across the models we have estimated for CS/v. This judgment considers both their signs and statistical significance. Virtually all the decisions on the assumptions associated with qualitative modeling strategies were statistically significant factors in determining the real consumer surplus CS/v estimates.

When the variables are interpreted in terms of the classification used in developing equation (7), the key economic assumptions (such as the inclusion of a substitute price or measure of the implicit costs of travel time) are generally significant determinants of the estimate for the CS/v and conform to a priori expectations. The variable describing how site usage was measured indicates smaller benefits per unit in terms of days than trips. The parameter restrictions implicit in the use of a regional travel cost model appear to increase estimates of CS/v. This finding is difficult to explain based on prior theory. The restrictions imposed by the regional travel cost model have implications for the implicit extent of a recreation market, for whether sites are considered equivalent (by recreationists) in terms of the estimated demand responses to own price and income, and for the definition of what constitutes a substitute site.

The variables describing the functional form and estimator are classified as data based. This is based on our belief that analysts often engage in a pretesting process, either explicit or implicit. Results from different estimates are compared as part of the development of the "final" reported results. One way of evaluating the sensitivity of estimates to data specific judgments is to test the null hypothesis that the variables associated with these decisions do not exert a significant influence on CS/v. Using the sum of squared residuals for the models in columns (6) and (7), an F-test yields a decisive rejection of this hypothesis at the 1% significance level.

The effects of two variables deserve further discussion. The qualitative variable for the use of a maximum likelihood estimator (ML-Trunc) indicates whether the estimates attempt to adjust for the intercept nature of the data used in most microlevel recreation surveys. The negative and significant coefficient indicates that adjustment tends to reduce CS/v estimates. This probably reflects the evidence of the Smith and Desvousges (1985) study comparing ordinary least squares and a maximum likelihood estimator designed for truncation and censoring problems in an intercept survey (because it contributed a large number of the estimates for this evaluation). The second variable relates to the functional form specified for the demand model. Both loglinear and semilog specifications appear to increase CS/v over results with a semilog for the independent variables.

The type of recreation site and the primary activities supported by a site have distinctive effects. This finding requires careful interpretation because the site definitions are not mutually exclusive categories. For example, a trip to a lake in a national park would be worth \$19.94 more than one of the comparable length to a coastal area (i.e., the sum of the coefficient for national park, 41.13, and that of lake, −21.19 based on the model in column (8) of table 2). The results also suggest that wilderness sites and developed camping sites have similar consumer surplus estimates. This latter finding seems implausible, given the activities involved, and probably results from the small number of travel cost estimates for wilderness areas (i.e., about 10 of the 399 used in the models).

Implications

As the literature reporting benefit estimates for environmental resources expands, the task of summarizing what we know and how to use it in evaluating new policies becomes more difficult. The results reported here have implications for three types of questions. First, the studies under review span a period during which the conceptual models, data sets, and estimators for recreation demand analysis improved. Thus, they permitted an evaluation of the implications of a wide range of modeling judgments for consumer surplus (i.e., CS/v) estimates. Second, the studies also include an array of different types of recreation sites, allowing for the relative importance of the type of site for CS/v. Finally, the findings have implications for the feasibility of using econometric reviews of the empirical benefits literature in evaluating benefits transfer for policy analysis.

Overall, the results indicate that econometric methods can summarize the results from diverse empirical studies. Indeed, in our specific application (travel cost recreation demand models), this approach provided clear support for the issues identified in the theoretical and recent empirical literature as central to implementing the model. These include: (*a*) the implications of the treatment of an individual's time constraints for

his (or her) opportunity costs of time (Bockstael, Strand, and Hanemann); (*b*) the identification and treatment of substitute sites in modeling recreation demand (Rosenthal 1985, 1987); and (*c*) the adjustment of estimates from on-site microdata sets for the specification effects of these sampling procedures (Shaw).

The model selected as the best overall summary also provided some specific insights into the consequences of modeling judgments on each of these issues. For example, based on existing studies, use of an average wage rate or income per hour to measure the opportunity cost of time should reduce CS/v relative to its value with an individual-specific wage estimate. Equally important, the multiple used in the Cesario-Knetsch adjustment to wages has a significant effect on benefit estimates. The range is generally suggested to be between .25 and .50 with the usual value adopted about .33. Our model suggests this decision could lead to a $12.15 difference in the consumer surplus per unit of use. A failure to consider substitutes increases CS/v estimates. Finally, the effects of adjusting for the truncation effects of on-site surveys can be large, reducing the CS/v by over $50 from the OLS estimates.

Overall, meta-analytic summaries have considerable promise in evaluating the sensitivity of estimates of the values of nonmarketed recreation (and other environmental resources) to modeling assumptions. Because these studies generally have been based on site-specific data, econometric summaries of their findings are more likely to provide new insights than with macro applications where analysts often deal with the same aggregate data. Nonetheless, at this stage it would not be prudent to recommend this type of model for predicting CS/v for policy analysis. Rather, this approach can serve as a consistency check to the processes used in benefits transfer analyses for policy. More explicit use should await further research on the properties of meta-analytic summary models.

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Appendix

Real Consumer Surplus per Unit of Use and Own-Price Elasticity of Demand

Author	Identification Number	Number of Estimates	Range (Estimate) (CS/v)	Range (Estimate) Own-Price Elasticity
Samples and Bishop	1	11	.11–6.24	
Ribaudo and Epp	2	1	3.66	−.49
Rosenthal [1985]	4	22	.46–5.85	−1.79 to −4.58
Sellar	5	11	2.89–15.17	−0.003 to −0.02
Sorg, Loomis, Donnelly, Peterson, Nelson	13	51	9.19–20.81	
Haspel and Johnson	17	6	20.60–36.84	
Menz and Wilton	22	5	9.02–20.60	−1.49
Mullen and Menz	23	3	7.41–13.12	
Brown, Sorbus, Chou-Yang, and Richards	25	1	15.93	
Sinden	34	1	.29	−.54
Capel and Pandey	37	1	9.26	−1.05
Sutherland (1982a)	45	40	1.36–40.32	
Smith and Desvousges (1985)	51	44	1.97–219.78	−.04 to −2.99
Smith, Desvousges, and Fisher	52	1	7.21	
Loomis (1986a)	62	1	12.53	
Loomis (1986b)	63	3	11.53–22.36	−1.63 to −1.71
Klemperer, Buhyoff, Verbyla, and Joyner	67	8	.92–3.90	

Appendix

Continued

Author	Identification Number	Number of Estimates	Range (Estimate) (CS/v)	Own-Price Elasticity
Sorg and Nelson	71	2	21.20–33.50	
Sorg, Loomis, Donnelly, Peterson, and Nelson	72	4	13.23–14.41	
Donnelly, Loomis, Sorg, and Nelson	73	2	6.67–9.35	
Farber	79	1	17.45	
Sublette and Martin	82	4	7.88–37.54	
Vaughan and Russell	84	4	3.23–7.88	
Sawyer	96	1	48.11	−.17
Osborn	97	1	88.07	−.27
Green	98	2	59.96–146.95	−.0016 to −.005
McCollum	99	28	8.06–146.95	
Sorhus	103	4	9.23–28.47	−.73 to −.81
Shalloof	105	8	49.14–91.59	
Adrangi	109	2	7.68–10.02	
Daniels	112	5	4.99–6.23	−5.97 to −6.96
Huang	113	43	4.93–60.20	−.05 to −.84
Tambunan	114	73	4.77–327.22	−.0003 to −.93
Smith and Kopp	115	2	4.22–11.84	−1.59 to −1.71
Smith (1975)	116	2	5.03	

Note: These results are for only those studies included in our most detailed model based on 399 estimates from 35 studies.

Theoretical and Empirical Advantages of Truncated Count Data Estimators for Analysis of Deer Hunting in California

Michael D. Creel and John B. Loomis

Truncated Poisson and truncated negative binomial count data models, as well as standard count data models, OLS, nonlinear normal, and truncated nonlinear normal MLE were used to estimate demand for deer hunting in California. The truncated count data estimators and their properties are reviewed. A large sample ($N = 2223$) allowed random segmenting of the data into specification, estimation, and out-of-sample prediction portions. Statistics of interest are therefore unbiased by the specification search, and the prediction results allow comparison of the statistical models' robustness. The new estimators are found to be more appropriate for estimating and predicting demand and social benefits than the alternative estimators based on a variety of criteria.

Key words: recreational demand, truncated count data models, travel cost models.

Surveys of users visiting a site are often employed to collect data on recreational demand. Given such a sampling method, no data will be collected for individuals taking zero trips to a site. The sample will therefore be truncated at the zero trip level. A second feature of recreation studies is that the dependent variable is often the count of the number of trips taken over the season or year. As such, it will be a nonnegative integer. The observed dependent variable is therefore the outcome of a data-generating process (DGP) based on some unknown probability distribution function defined on the nonnegative integers, which may be termed a count data process. The combination of a truncated sample from a count data process suggests that estimators based on truncated count data distributions may be called for.

Figure 1 illustrates the bias encountered in using an estimator which is uncorrected for sample truncation and shows what a count data process might look like. Let $Y = f(X, \beta, \epsilon)$, and let Y be distributed by some known count data process such that Y can take on the values $i \in \{0, 1, 2\}$. Assume that X is a matrix of nonstochastic independent variables, β is a parameter vector, and ϵ is a random disturbance. The heights of the curved lines above the lines $Y = i$ represent $p(Y = i|X, \beta)$. The heights of these lines sum to one in the vertical dimension. Line A represents $E(Y|X, \beta)$ and line B represents $E(Y|X, \beta, Y > 0)$. Assume a sample is taken from the population such that Y is observed only if $Y > 0$. The parameter estimates from a maximum likelihood estimator based on the known distribution of Y that is not corrected for the sample truncation will be biased and inconsistent since the regression will be approximating line B rather than line A. In the context of modeling demand, if Y is quantity and X is price, the uncorrected estimator's parameter estimates will most likely overstate Marshallian consumers' surplus because line B everywhere lies outside of line A. In most policy-relevant welfare economics problems, one wishes to estimate *ex ante* social benefits after changes in exogenous variables (e.g., site quality, season length) occur rather than estimate *ex post* benefits already received by the persons in the sample. Therefore, the population or unconditional demand curve (line

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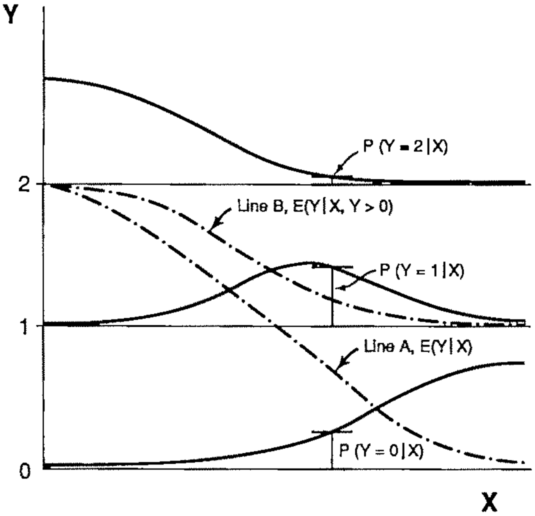

Figure 1. Truncation bias for a known count data process

A), should be the focus of interest. Shaw (1988b) presents a similar figure for the case of a normally distributed random variable. Truncation bias is further discussed in general by Maddala, and in the recreational demand literature by Smith, Desvousges, and Fisher; Smith; and McConnell and Kling.

Count data estimators may better fit data from a count data process than would a continuous distribution-based estimator. Count data estimators restrict positive probability assignment to possible events, while continuous distribution estimators give positive probability to fractional and possibly negative values of the dependent variable. The importance of respecting the count data nature of the dependent variable may depend on the problem at hand. As Larson shows, the normal distribution is a good approximation of the Poisson distribution if the Poisson parameter λ, which is usually parameterized such that λ_i is the conditional mean of the dependent variable Y_i, is large. Thus, if the DGP is truly a Poisson process, normal MLE may be a suitable procedure if the conditional mean of the dependent variable is large, but it may not give acceptable results if the conditional mean of Y_i is small. One should be cautious in using normal MLE to model a count data process for which small values of the dependent variable are common. A given count data distribution may be the true distribution underlying the DGP, but any continuous distribution is known a priori to be incorrect.

Poisson and negative binomial count data models have been used in numerous recent studies, including Hausman, Hall and Griliches' work on patents issued and Cameron and Trivedi's study of doctor visits. Smith employed a Poisson travel cost model to estimate demand for water-based recreation trips. Grogger and Carson (1987, 1988) introduced truncated Poisson and truncated negative binomial count data estimators. In their papers they present results of using standard untruncated count data estimators as well as their truncated estimators to estimate demand for fishing trips in Alaska. Finally, Shaw (1988a) presented a truncated Poisson estimator appropriate for endogenously stratified samples, and conducted some Monte Carlo simulations.

This paper presents results of employing Poisson (POIS), truncated Poisson (TPOIS), negative binomial (NB), and truncated negative binomial (TNB) maximum likelihood estimation as well as ordinary least squares (OLS), nonlinear normal (NLS), and truncated nonlinear normal (TNLS) MLE to estimate a travel cost method demand curve for deer hunting in California. A large sample (N = 2,223) was randomly segmented into specification, estimation and prediction portions. The following sections (*a*) present versions of Grogger and Carson's estimators for the case of truncation at the zero level and review their properties; (*b*) describe the specification-estimation-prediction methodology and present the estimation results; (*c*) compare the out-of-sample predictive performances of the models; and (*d*) give point estimates of consumers' surplus per trip for the various statistical models.

The Estimators

The Poisson probability law is

$$(1) \qquad f(W = w) = \frac{\exp(-\lambda)\lambda^w}{w!},$$

which is a discrete density function defined for w an element of the set of nonnegative integers. The parameter $\lambda > 0$ is both the mean and variance of the random variable W. If the elements of an $N \times 1$ (where N is the sample size) dependent variable vector Y are distributed independent Poisson (λ) and λ varies by observation as a function of an $N \times K$ matrix of explanatory variables X and a $K \times 1$ parameter vector β, as in

$$(2) \qquad \lambda_i = \exp(X_i\beta)$$

or, for the whole sample, in matrix notation:

$$(2.1) \qquad \lambda = \exp(X\beta),$$

then the standard Poisson likelihood function obtains:

$$(3) \qquad \ln L = -s'\lambda + Y'X\beta - s'\ln[Y!],$$

where s is an $N \times 1$ sum vector and the logarithmic and factorial functions are element-by-element.

Noting that $F(W = 0) = f(W = 0) = \exp(-\lambda)$, where $F(\cdot)$ indicates the cumulative density function (CDF) and $f(\cdot)$ indicates the probability density function (PDF), the conditional Poisson density function may be expressed as

$$(4) \quad f(W = w|W > 0) = \frac{\exp(-\lambda)\lambda^{w}}{w!}\left[\frac{1}{1 - \exp(-\lambda)}\right].$$

Maintaining the above notation and allowing λ to vary as in (2), the zero-level truncated Poisson likelihood function may thus be written as

$$(5) \quad \ln L = -s'\lambda + Y'X\beta - s'\ln[s - \exp(-\lambda)] - s'\ln[Y!].$$

A characteristic of the standard Poisson model is that the conditional mean of the dependent variable, λ, is equal to the conditional variance, i.e., the variance-mean ratio is unity. Overdispersion of the population is defined as the conditional variance of the dependent variable exceeding its conditional mean, giving a variance-mean ratio greater than unity. Overdispersion is thus a form of heteroscedasticity. If the population is overdispersed and the conditional mean is correctly specified as the true mean of the DGP, possibly as in (2), the untruncated Poisson model will give consistent estimates of the parameters but downwardly biased estimates of their standard errors (Gourieroux, Monfort, and Trognon 1984a, p. 707; Grogger and Carson 1987, p. 4). The truncated Poisson estimator is biased and inconsistent in the presence of overdispersion, since this estimator is based on the higher moments of the Poisson distribution through the CDF term in (4), which are incorrect given that the DGP embodies overdispersion (Grogger and Carson 1988, p. 7). Analogously, the standard Poisson estimator is biased and inconsistent when applied to a truncated sample since the conditional mean is misspecified as was illustrated in figure 1. The fact that both estimators are inconsistent if the sample is truncated and overdispersed makes the truncated negative binomial estimator an attractive generalization if these conditions are present.

The negative binomial probability law may be written as

$$(6) \quad f(Z = z) = \frac{\Gamma(z + 1/\alpha)}{\Gamma(z + 1)\Gamma(1/\alpha)}(\alpha\lambda)^{z}(1 + \alpha\lambda)^{-(z+1/\alpha)},$$

where $\Gamma(\cdot)$ indicates the gamma function. This is a discrete PDF defined for z, an element of the set of nonnegative integers, with parameters $\alpha > 0$ and $\lambda > 0$. The mean of the random variable Z is λ and its variance is $\lambda + \alpha\lambda^2$, which is everywhere greater than the mean. The variance-mean ratio is $1 + \alpha\lambda$, so the degree of overdispersion is an increasing function of both α and λ. This is the same distribution as found in Lee's equation 4.9 (Lee, p. 698) where our α is equivalent to Lee's $\delta/(1 - \delta)$. It may be derived by letting the Poisson parameter be distributed as a gamma random variable with mean λ and variance $\alpha\lambda^2$. As $\alpha \rightarrow 0$ the gamma distribution becomes degenerate and the negative binomial distribution reduces to a Poisson distribution. If the elements of the $N \times 1$ dependent variable vector Y are distributed independent negative binomial (λ, α) and λ varies by observaton as in (2) and α is an estimated constant for the population controlling the level of overdispersion, one of the possible negative binomial statistical models results with likelihood function given by

$$(7) \quad \ln L = s'\ln[\Gamma(Y + s/\alpha)] - s'\ln[\Gamma(Y + s)] - N\cdot\ln[\Gamma(1/\alpha)] + \ln(\alpha)s'Y + Y'X\beta - (Y + s/\alpha)'\ln[s + \alpha\lambda].$$

Note that for this density function,

$$(8) \quad F(Z = 0) = f(Z = 0) = (1 + \alpha\lambda)^{-(1/\alpha)}.$$

Bayes' theorem can be used to write the conditional negative binomial density function:

$$(9) \quad f(Z = z|Z > 0) = \frac{\Gamma(z + 1/\alpha)}{\Gamma(z + 1)\Gamma(1/\alpha)} \cdot (\alpha\lambda)^{z}(1 + \alpha\lambda)^{-(z+1/\alpha)}\left[\frac{1}{1 - (1 + \alpha\lambda)^{(-1/\alpha)}}\right].$$

Using the same notation as above and again allowing λ to vary as in (2), the zero-level truncated negative binomial likelihood function may be written:

$$(10) \quad \ln L = s'\ln[\Gamma(Y + s/\alpha)] - s'\ln[\Gamma(Y + s)] - N\cdot\ln[\Gamma(1/\alpha)] + \ln(\alpha)s'Y + Y'X\beta - (Y + s/\alpha)'\ln[s + \alpha\lambda] - s'\ln[s - (s + \alpha\lambda)^{(-1/\alpha)}],$$

where all operations other than matrix products are element by element.

Under a set of regularity conditions (Gourieroux, Monfort, and Trognon 1984b, appendix), the truncated Poisson and truncated negative binomial estimators will be consistent provided their conditional means are specified as underlies the true DGP (see Grogger and Carson 1987, appendix). If the dependent variable exhibits overdispersion, the truncated Poisson estimator will be inconsistent because its mean depends on the incorrect higher moments of the Poisson distribution, while the truncated negative binomial estimator will be consistent if the DGP is truly the above truncated negative binomial process and (2) is a correct specification of the population mean. Larson (pp. 171, 188) provides some diagrams which aid in understanding the differences between the count data models. The next section presents an application of these estimators as well as estimators based on the normal distribution to data of deer hunting in California.

Specification and Estimation

The data for this study were collected by a mail survey of California deer hunters who purchased a deer hunting license in 1987. There is no endogenous stratification in a mail survey (i.e., frequent visitors are no more likely to be sampled than infrequent visitors), so Grogger and Carson's estimators are appropriate rather than Shaw's truncated Poisson estimator. This paper focuses on hunters who took trips to one of seventeen X zones, one of the four types of hunting zones in California. X zones are located in northeastern California, for the most part. Before each hunting season, potential hunters (those persons with some propensity to hunt, though not necessarily currently active hunters) must decide whether or not to hunt. If the decision is to hunt, a license must be purchased. The license is valid for only one of the thirty-five hunt zones in California. If a license is purchased, the hunter may take as many trips to the zone as desired during the season, subject to a bag regulation.

We view this decision process as one of two stages. First a potential hunter decides which hunting zone is preferred, then the hunter decides how many trips to take to this zone. Site preference was modeled with a multinomial logit model, not discussed further in this paper. Hunters who preferred an X zone define the statistical population of the X zone trip frequency model, which is the focus of this paper. The unobserved zeros of the dependent variable (number of trips taken to an X zone) are a result of potential hunters who preferred to hunt in an X zone but decided not to purchase a license or, having purchased a license, failed to take any trips. A model treating hunters that visited non-X zones as observed zeros of an untruncated model of X zone visitation would be inappropriate for this problem, where there is no possibility of visiting other zones once the site preference decision has been made. This paper addresses only the trip frequency stage of the decision-making process. The seventeen X zones are treated as one destination, which may be thought of as imposing untested (but testable) coefficient restrictions across seventeen separate trip frequency models. This was done to facilitate comparing the statistical models and admittedly may not result in the best estimates for a particular X zone.

The general specification of the travel cost model was

$$(11)\quad Y_i = f(PRICES_i,\ SITE\ QUALITY_i,\ INDIVIDUAL\ CHARACTERISTICS_i,\ \phi,\ \epsilon_i)$$

or, in general matrix notation:

$$(12)\qquad Y = f(X, \phi, \epsilon),$$

where X is the matrix of independent variables ϕ is a vector of parameters (not limited to coefficients of independent variables), and ϵ is a vector of independent random disturbances. The dependent variable, Y, the number of trips taken to an X zone, is truncated at the zero level, as discussed above.

A candidate set of twenty explanatory variables was identified based on the above general specification; 2,223 survey responses contained valid observations of the entire set. The candidate set did not include travel costs to other sites due to the nonpossibility of substitution between sites after a license is purchased, as discussed above. These observations were randomly divided into three portions: a specification portion; an estimation portion; and a prediction portion of 707, 764, and 752 observations, respectively. The sample mean of the dependent variable, Y was 2.76 for the estimation portion of the data. This low mean suggests that the normally distributed specifications may provide a poor approximation to the true DGP.

The statistical models fitted were the following:

$$\text{OLS:}\qquad Y \sim N(X\beta, \sigma^2 I)$$

$$\text{NLS:}\qquad Y \sim N(\mu = \exp(X\beta), \sigma^2 I)$$

TNLS: $Y \sim N(\mu = \exp(X\beta), \sigma^2 I)$, Y observed only if $Y > 0.5$

POIS: $Y \sim Pois(\lambda = \exp(X\beta))$

TPOIS: $Y \sim Pois(\lambda = \exp(X\beta))$, Y observed only if $Y > 0$

NB: $Y \sim NB(\lambda = \exp(X\beta), \alpha)$

TNB: $Y \sim NB(\lambda = \exp(X\beta), \alpha)$, Y observed only if $Y > 0$.

The nonlinear truncated normal model is a standard lower truncated normal model as discussed in Maddala, with the exception of the nonlinear specification of the mean. The 0.5 lower truncation limit for the TNLS model was chosen as a continuity correction between the limits of 0 or 1, which, as Larson (pp. 296, 299) indicates, should allow the normal distribution to better approximate the unknown true count data DGP. Attempts were made to fit a linear ($\mu = X\beta$) truncated normal model, but convergence was not achieved. The count data models were as discussed above. Estimation programs written in the Gauss programming language are available from the authors.

Using the specification data, various combinations of explanatory variables and data transformations were used to fit all the statistical models. A semilog form (for the continuous distribution estimators, OLS, NLS and TNLS) gave a worse fit in all cases. Logarithms of continuous right-hand side (RHS) variables gave a slightly better fit in some cases, but were not used due to the arbitrariness of the resulting social benefit estimates. Quadratic forms of some variables (e.g., *AGE*, and *INCOME*) did not improve the results.

Ten independent variables including a constant were selected, based on theory and overall performance for each of the seven different statistical models. Some variables which were not significant for all of the statistical models were left in the final variable set to avoid omitted variable bias, as in the case of travel time. It would be possible to improve the fit of any of the models somewhat by selecting a model-specific set of variables, but in the interest of comparability a uniform set was chosen.

These variables were: *TC*, round trip travel cost at \$0.22 per mile, the sample average; *TIME*, round trip travel time in hours (experimentation using the specification data, with wage-weighting of travel time did not fit as well as time alone); *DAYS*, the individual's average length of trip; *YEARS*, the number of years the individual had previously hunted at the zone; *BAG*, a zero one dummy, equal to 1 if a deer was taken in the 1987 season; *PASNO*, the number of times the individual passed up an opportunity to take a deer; *DEERSN*, the number of deer seen on the last trip of the season; *INCOME*, household income in thousands of dollars; and *SEASON*, zone hunting season length in days.

Next, the above variables arrived at using the first portion ($N = 707$) of the data were used to estimate all the statistical models, using the estimation portion ($N = 764$) of the data. This was a one-time, first-try estimation for this data; therefore the results are free from any form of pretest bias. As such, the reported t-statistics and goodness-of-fit measures are unbiased by the specification search and are a fair means of comparing the statistical models' performance, insofar as the selection of included variables was fair. Estimation results are found in table 1.

All of the coefficient estimates are of the expected sign for all of the statistical models (a negative sign on the income coefficient is often encountered with travel cost models, see Duffield; Mendelsohn; or Grogger and Carson 1987, for instance). The truncated models are generally more elastic in all variables, which is expected, as in figure 1. In general, POIS is in closer agreement to NB than it is to TPOIS, and TPOIS is closer to TNB than it is to POIS. This suggests that the effect of truncation is more important than the effect of overdispersion. Given the significance of alpha, which reflects the level of overdispersion (see above) in the NB and TNB models, the hypothesis of no overdispersion can be rejected. The presence of overdispersion implies that the t-statistics of both POIS and TPOIS are biased away from zero, which may explain why they are almost always larger in absolute value than the corresponding t-statistics of the negative binomial models. Because the sample exhibits truncation and overdispersion the only potentially unbiased count data model is the TNB. Based on this fact and a good fit and t-statistics, the TNB statistical model seems superior to the alternative count data models. The OLS model is clearly inferior to the alternatives, while NLS and TNLS give results comparable to the count data models.

Prediction

The third step of the study was to use the coefficients estimated for the various statistical models using the estimation portion of the data to pre-

Table 1. Estimation Results

	OLS	NLS	TNLS	POIS	TPOIS	NB	TNB
ONE	4.674	1.827	2.190	1.560	1.603	1.514	1.332
	(6.38)	(7.92)	(5.67)	(9.75)	(8.11)	(7.28)	(3.68)
TC	−0.0118	−0.00578	−0.0272	−0.0065	−0.0134	−0.0061	−0.0143
	(−3.43)	(−2.19)	(−3.96)	(−6.40)	(−8.37)	(−5.66)	(−8.10)
TIME	−0.0517	−0.0977	−0.175	−0.0245	−0.0326	−0.0174	−0.0169
	(−1.45)	(−3.56)	(−2.79)	(−2.38)	(−2.11)	(−1.61)	(−1.05)
DAYS	−0.154	−0.0547	−0.057	−0.0442	−0.0481	−0.0385	−0.0495
	(−4.47)	(−3.95)	(−3.12)	(−6.00)	(−5.70)	(−4.31)	(−3.56)
YEARS	0.0374	0.0122	0.0186	0.00991	0.011	0.00902	0.0106
	(3.58)	(5.46)	(6.32)	(5.19)	(5.26)	(3.50)	(2.56)
BAG	−0.252	−0.104	−0.189	−0.0783	−0.104	−0.0747	−0.147
	(−1.05)	(−1.67)	(−2.20)	(−1.59)	(−1.84)	(−1.15)	(−1.36)
PASNO	0.226	0.0267	0.0326	0.0335	0.03	0.0397	0.0622
	(3.77)	(4.11)	(3.81)	(4.56)	(3.96)	(2.97)	(2.36)
DEERSN	0.0012	0.000962	0.001	0.000644	0.000776	0.000511	0.000655
	(1.81)	(4.05)	(3.38)	(2.96)	(3.11)	(1.74)	(1.31)
INCOME	−0.0187	−0.00777	−0.0144	−0.00626	−0.00814	−0.00614	−0.0108
	(−3.79)	(−4.43)	(−4.67)	(−5.37)	(−5.54)	(−4.17)	(−4.11)
SEASON	0.0299	0.0237	0.0258	0.0214	0.0332	0.0183	0.0364
	(0.71)	(1.74)	(1.10)	(2.28)	(2.84)	(1.50)	(1.72)
ALPHA	N/A	N/A	N/A	N/A	N/A	0.216	0.754
						(8.51)	(5.19)
SIGMA	2.9	2.59	2.83	N/A	N/A	N/A	N/A
R-SQUARED	0.242	0.389	0.341	0.354	0.403	0.332	0.326
Log-*L*	−1892.9	−1810.4	−1523.5	−1539.1	−1295.8	−1443.2	−1145.6

[a] *T*-statistics are in parentheses.

dict the number of trips taken in the prediction portion of the data ($N = 752$), conditional on the prediction portion's independent variables. This allows us to assess the robustness of the estimators and their relative usefulness in estimating consumers' benefits. Predictive ability is measured by R^2, by the difference between total predicted and total actual trips, and by percentage error. The prediction results are found in the upper portion of table 2.

Based on out-of-sample R^2, the count data models predict substantially better than do OLS and TNLS. TNLS performs strikingly poorly out-of-sample, achieving an R^2 of only 0.023 and overpredicting trips by 40.9%. NLS predicts about as well as the count data models. For all the statistical models, the difference between in-sample and out-of-sample R^2 is somewhat greater for the truncated models than for the corresponding untruncated models. In terms of predicting total trips taken, the POIS model is clearly superior, and TNLS is clearly inferior.

Benefit Estimates

Point estimates of consumers' surplus per predicted trip ($\hat{C}/\hat{Y}$) are found in the last line of table 2. As argued in the introduction, the unconditional population demand curve is usually of most interest in most welfare economics problems. Thus, for the truncated models, the results presented use the predictor $\hat{Y} = E(Y|X)$ rather than $\hat{Y} = E(Y|X, Y > 0)$. For OLS the formula is $\hat{C}/\hat{Y} = -\hat{Y}/(2\hat{\beta}_{TC})$, where $\hat{Y}$ is the predicted value of Y calculated at the means of the independent variables, and for all the other models the formula is $\hat{C}/\hat{Y} = -1/\hat{\beta}_{TC}$. These consumers' surplus figures are conditional on the site selection decision already having been made. Once a license is purchased, there is no possibility of substitution between zones. An alternative procedure would be to calculate welfare measures unconditional on site choice, using a joint site selection/trip frequency model. The truncated models give a lower estimate than do the corresponding untruncated models, as is expected from figure 1. This effect is most apparent in the NLS-TNLS pair. The truncated models attempt to fit the population unconditional demand curve analogous to line A of figure 1, while the untruncated models attempt to fit a line analogous to line B. For the count data models, allowing for overdispersion has little effect on the estimate, as is seen by comparing the pairs POIS-NB and TPOIS-TNB.

Conclusions

Several results are indicated by this study. First, accounting for truncation of the dependent variable makes a substantial difference in the coefficient estimates, and subsequently, in benefit estimates, regardless of the choice of statistical model.

Second, the TNLS model is not robust in the sense that it does not perform well out-of-sample, and it would be a poor choice to predict visitation. The conditional mean of this model is

$$(13)\quad E[Y|X, Y > 0] = \exp(X\beta) + \frac{\sigma\phi[(X\beta - .5)/\sigma]}{\Phi[(X\beta - .5)/\sigma]},$$

where $\phi[\cdot]$ and $\Phi[\cdot]$ are the density and distribution functions of a standard normal random variable, respectively. If the assumption of homoscedasticity is not justified, the parameter estimates of this model would be biased through the misspecified distribution function term in the likelihood function. If the DGP is characterized by the conditional variance increasing with the conditional mean, as is embodied in the count data models, the TNLS model will overcom-

Table 2. Out-of-Sample Prediction Results and Estimated Consumer Surplus

	Statistical Model						
	OLS	NLS	TNLS	POIS	TPOIS	NB	TNB
R-squared	0.233	0.297	0.027	0.346	0.334	0.328	0.301
Act-pred trips	−121.9	50.5	−775.0	16.0	−132.8	−99.1	−74.1
(Act-pred)/act (%)	−6.6	2.7	−40.9	0.9	−7.2	−5.4	−4.0
CS/pred trips ($)	117.25	172.82	36.72	153.62	74.71	163.05	70.07

Note: Out-of-sample prediction results are prediction data, total actual trips = 1,845; estimated consumer results from estimation data.

pensate for truncation at low levels of the dependent variable, since σ will be too large and $\Phi[\cdot]$ will be too small. This overcompensation would serve to make the term $\exp(X\beta)$ in [13] small, which would tend to bias the price coefficient downward. This is reflected in the low consumers' surplus per trip estimate from this model. This bias may be sensitive to the number of outlying (large) observations of the dependent variable, which strongly influence the estimate of σ; this sensitivity would explain the lack of robustness exhibited by this model's spectacular overprediction of trips for the out-of-sample data.

A third result is that the data do appear to exhibit overdispersion. The hypothesis of no overdispersion (H0: $\alpha = 0$) is rejected with a high degree of confidence using either the NB or TNB models. Thus, the relatively large t-statistics of the POIS and TPOIS models should be viewed with suspicion, (recalling that these models' standard errors are biased downward if there is overdispersion) and bias suspected in the TPOIS model due to incorrect higher moments. The coefficient estimates of all the untruncated models are probably biased due to the sample truncation. Given these results, and given the poor performance of the TNLS model out-of-sample, the TNB model is the best suited of the models studied to estimating demand and social benefits for this data.

This paper has two messages. First, truncated count data models present a useful and perhaps better way to analyze a broad class of problems not limited to recreational demand. Second, the specification-estimation-prediction methodology should be more widespread. Elimination of specification bias and "clean" goodness-of-fit and t-statistics are necessary to evaluate a model, and they are positive aspects of the procedure. For smaller samples, the prediction step might be skipped (perhaps at the cost of failing to identify poor models such as the TNLS model here). The use of an entire large sample to both specify and estimate a model is an inefficient use of data in that bias is introduced to what are likely satisfactorily efficient estimates.

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Elasticities in AIDS Models

Richard Green and Julian M. Alston

In the literature, a variety of approaches have been used to calculate demand elasticities in almost ideal demand system (AIDS) models of demand. It is common to estimate the linear approximate almost ideal demand system (LA/AIDS) instead of the AIDS. When the LA/AIDS is estimated, all of the previously reported approaches to compute elasticities are theoretically incorrect. This paper presents correct formulas for LA/AIDS elasticities and illustrates the potential errors from using incorrect computing formulas.

Key words: AIDS and LA/AIDS models, computing formulas, elasticities.

The almost ideal demand system (AIDS) of Deaton and Muellbauer (1980a,b) has become popular in recent years (Anderson and Blundell; Blanciforti and Green 1983a,b; Blanciforti, Green, and King; Chalfant; Eales and Unnevehr; Fujii, Khaled, and Mak; Fulponi, Heien and Willett; Murray; Parsons; Ray). A variety of approaches to computing elasticities has been used, and some of the approaches may lead to significant errors. This paper clarifies the differences between alternative approaches to estimating demand elasticities in AIDS models.

The AIDS Model

The AIDS model is usually specified as

$$(1) \qquad w_i = \alpha_i + \sum_j \gamma_{ij} \ln P_j + \beta_i \ln\left(\frac{X}{P}\right),$$

where X is total expenditure on the group of goods being analyzed, P is the price index for the group, P_j is the price of the jth good within the group, w_i is the share of total expenditure allocated to the ith good (i.e. $w_i = P_i Q_i / X$), and the price index (P) is defined as

$$(2) \qquad \ln P = \alpha_0 + \sum_j \alpha_j \ln P_j + \frac{1}{2} \sum_j \sum_i \gamma_{ij} \ln P_i \ln P_j.$$

The Linear Approximate AIDS (LA/AIDS) Model

Using the price index from equation (2) often raises empirical difficulties, especially when aggregate annual time-series data are used, and it is common to use Stone's (geometric) price index (P^*) instead of P:

$$(3) \qquad \ln P^* = \sum_k w_k \ln P_k.$$

The model that uses Stone's index is called the "linear approximate AIDS" (LA/AIDS) following Blanciforti and Green (1983a). If prices are highly collinear, P may be approximately proportional to P^*, i.e., $P \cong \zeta P^*$. In the extreme case when P is exactly (linearly) proportional to P^*, the LA/AIDS model can be used to estimate the parameters of the AIDS model because, then, the LA/AIDS can be written (in terms of the AIDS model parameters) as

$$(4) \qquad w_i = (\alpha_i - \beta_i \ln \zeta) + \sum_j \gamma_{ij} \ln P_j + \beta_i \ln\left(\frac{X}{P^*}\right).$$

More generally, however, the relationshp between the parameters of the AIDS and the corresponding parameters of the LA/AIDS is not known.[1] In addition, it is not known whether the LA/AIDS has satisfactory theoretical properties. These issues notwithstanding, the LA/AIDS is very popular.

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[1] The AIDS and the LA/AIDS are actually nonnested systems. However, as the Stone's index becomes a better and better proxy for the price index in (2), the estimates from the LA/AIDS would approach the estimates for the AIDS except for the intercept term.

Price Elasticities

A general definition of the uncompensated elasticities of demand from the AIDS and LA/AIDS (η_{ij}) is

$$(5)\quad \eta_{ij} = \frac{d\ln Q_i}{d\ln P_j} = -\delta_{ij} + \frac{d\ln w_i}{d\ln P_j} = -\delta_{ij} + \left\{\gamma_{ij} - \beta_i \frac{d\ln P}{d\ln P_j}\right\}\Big/ w_i,$$

where these elasticities refer to allocations within the group holding constant total group expenditures (X) and all other prices (P_k, $k \neq j$), δ_{ij} is the Kronecker delta ($\delta_{ij} = 1$ for $i = j$; $\delta_{ij} = 0$ for $i \neq j$) and for the LA/AIDS we use P^* from (3) instead of P from (2).

The differences in the literature can be represented in terms of different expressions for the elasticity of the group price index with respect to the jth price (i.e., $d\ln P/d\ln P_j$ or $d\ln P^*/d\ln P_j$). These differences carry over directly into the computation of compensated elasticities (η^*_{ij}), which are

$$(6)\quad \eta^*_{ij} = \eta_{ij} + w_j\left(1 + \frac{\beta_i}{w_i}\right).$$

In the AIDS model, the correct expression for the elasticity of the group price with respect to the jth price is

$$(7)\quad \frac{d\ln P}{d\ln P_j} = \alpha_j + \sum_k \gamma_{kj}\ln P_k.$$

Substituting (7) into (5) yields the correct elasticities for the AIDS. Several authors (e.g., Anderson and Blundell; Blanciforti and Green 1983a,b); Fulponi; Heien and Willett) have used the resulting computing formula for AIDS elasticities with parameters from the LA/AIDS.

To obtain the correct formula for the LA/AIDS, we differentiate Stone's price index with respect to the jth commodity price and get

$$(8)\quad d\ln P^*/d\ln P_j = w_j + \sum_k w_k \ln P_k \frac{d\ln w_k}{d\ln P_j}.$$

From (5) we have $d\ln w_i/d\ln P_j = \delta_{ij} + \eta_{ij}$, so that (8) may be written as

$$(8')\quad d\ln P^*/d\ln P_j = w_j + \sum_k w_k \ln P_k(\eta_{kj} + \delta_{kj}).$$

Notice the similarity between this expression for the LA/AIDS and equation (7) for the AIDS. An important difference is that when equation (8) is substituted into (5) or (6) the elasticity of interest is expressed in terms of itself and all of the other elasticities. In the case of n goods we have n^2 simultaneous equations for uncompensated demand elasticities of the form

$$(9)\quad \eta_{ij} = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} - \frac{\beta_i}{w_i}\left\{w_j + \sum_k w_k \ln P_k(\eta_{kj} + \delta_{kj})\right\}.$$

Equation (9) can be expressed in matrix form as

$$(10)\quad E = A - (BC)(E + I),$$

where the typical elements are $a_{ij} = -\delta_{ij} + (\gamma_{ij}/w_i) - \beta_i(w_j/w_i)$ in A (an $n \times n$ matrix); $b_i = (\beta_i/w_i)$ in B (an $n \times 1$ vector); $c_j = w_j \ln P_j$ in C (a $1 \times n$ vector); and η_{ij} in E (an $n \times n$ matrix). Solving for the elasticities $[\eta_{ij}]$ yields, after some simplifications,[2]

$$(11)\quad E = [BC + I]^{-1}[A + I] - I.$$

Several authors have used computing formulas for the LA/AIDS that may be seen as special cases of this result. A common approach (e.g., Chalfant; Fujii, Khaled, and Mak) is to use equations for elasticities of the form $\eta_{ij} = -\delta_{ij} + \{\gamma_{ij} - \beta_i w_j\}/w_i$, which obtain in the special case when $d\ln P^*/d\ln P_j = w_j$ (i.e., expenditure shares are constant). As a further special case, Eales and Unnevehr use an elasticity formula corresponding to $\eta_{ij} = -\delta_{ij} + \gamma_{ij}/w_i$. This is compatible with both AIDS and LA/AIDS under the assumption that either preferences are homothetic ($\beta_i = 0\ \forall i$) or the group price is constant, independent of individual goods' prices (i.e., $d\ln P^*/d\ln P_j = 0$).[3] In their application the latter assumption is appropriate.

Table 1 summarizes the different approaches to estimating uncompensated price elasticities from the AIDS and the LA/AIDS. Clearly, all of the formulas are identical when budget shares are invariant with income (i.e., $\beta_i = 0\ \forall i$; pref-

[2] The steps are as follows. First, add an identity matrix (I) to both sides of (10) to get $(E + I) = (A + I) - (BC)(E + I)$. Then add $(BC)(E + I)$ to both sides to get $(BC + I)(E + I) = A + I$. Then premultiply by $(BC + I)^{-1}$ to get $(E + I) = (BC + I)^{-1}(A + I)$.

[3] Parsons uses a formula for compensated elasticities that is the same as Eales and Unnevehr's formula for uncompensated elasticities. We cannot see conditions under which Parson's formula could be correct.

Table 1. Uncompensated Price Elasticities for the AIDS and the LA/AIDS

Model	Uncompensated Price Elasticity Formula η_{ij}	Estimates for Food Group: Meats	Fruits & Vegetables	Cereal & Bakery Products	Misc. Foods
AIDS[a]					
	$-\delta_{ij} + \gamma_{ij}/w_i - \beta_i\alpha_j/w_i - \frac{\beta_i}{w_i}\sum_k \gamma_{kj}\ln P_k$	−0.994	−0.256	−0.799	−0.787
LA/AIDS[b]					
(i)	$-\delta_{ij} + \gamma_{ij}/w_i - \beta_i\alpha_j/w_i - \frac{\beta_i}{w_i}\sum_k \gamma_{kj}\ln P_k$	−0.411	−0.229	−0.736	−0.325
(ii)	$-\delta_{ij} + \gamma_{ij}/w_i$	−0.664	−0.200	−0.888	−1.066
(iii)	$-\delta_{ij} + \gamma_{ij}/w_i - \beta_i w_j/w_i$	−0.988	−0.255	−0.811	−0.764
(iv)	$-\delta_{ij} + \gamma_{ij}/w_i - \beta_i w_j/w_i - \frac{\beta_i}{w_i}\left[\sum_k w_k \ln P_k(\eta_{kj} + \delta_{kj})\right]$	−0.996	−0.255	−0.810	−0.761

[a] Estimates from Blanciforti, Green, and King.
[b] All of these models refer to parameters estimated by the LA/AIDS. Model (i) uses the AIDS formula (e.g., Anderson and Blundell); model (ii) corresponds to Eales and Unnevehr with $d\ln P^*/d\ln P_j = 0$; model (iii) assumes $d\ln P^*/d\ln P_j = w_j$ (e.g., Chalfant); model (iv) is the correct formula for LA/AIDS.

erences are homothetic). When preferences are not homothetic the formulas differ, perhaps in important ways.

Empirical Work

Next, we compare the empirical results from the AIDS model and the four alternative approaches to estimate elasticities from LA/AIDS parameter estimates. Full information maximum likelihood estimates of the AIDS applied to U.S. food consumption data are reported in Blanciforti, Green, and King (p. 36) and those results were used to calculate the AIDS elasticities. Using the same data we estimated the LA/AIDS.

Table 1 reports the alternative measures of uncompensated elasticities (at the means of the sample data) implied by these estimates using the alternative formulas.[4] As can be seen from table 1, the elasticity estimates for any commodity are similar across the AIDS and the LA/AIDS models (iii) and (iv); but the estimates are quite different using the LA/AIDS models (i) and (ii).

In this example, the correct LA/AIDS model (iv) provided similar elasticities to the AIDS model, and the error from using model (iii) (which treats shares as exogenous) was small. However, large errors result from using model (i) (i.e., the AIDS formula with LA/AIDS parameters) or model (ii) (i.e., assuming the price index is exogenous).

We checked the sensitivity of these results for autocorrelation. In the LA/AIDS model, the estimated autocorrelation coefficient was 0.9017 with an asymptotic t-value of 22.0. When the estimates are corrected for autocorrelation the estimated β_i values for the various food groups are −0.002, 0.002, −0.095, and 0.094. Thus, correcting for autocorrelation in this particular application essentially reduces the real income effect to zero and the differences in the various elasticity expressions vanish.

Conclusions and Future Extensions

When the LA/AIDS is estimated, we recommend using the theoretically correct formula which has been developed here. Researchers should employ the AIDS price elasticity formula only when they have estimated the AIDS. In our empirical work these two approaches led to essentially identical elasticity estimates. However, that may be an artifact of the particular data set we analyzed. Monte Carlo studies would be needed in order to establish the conditions under which the LA/AIDS provides a close approximation to the AIDS. The authors are currently engaged in further work exploring some of these issues.

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[4] Only the own-price uncompensated elasticities are reported. The cross-price elasticities and other details of the estimation are available from the authors.

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The Demand for Cigarettes in Japan

Kim Haden

A two-stage budgeting procedure was used to estimate demand elasticities for cigarettes in Japan. Cigarettes were disaggregated into Japanese, U.S., and rest-of-world. Testing for habit effects was performed at both stages. Results indicated that habit effects occur for total expenditures on cigarettes but not between types.

Key words: cigarette demand elasticities, habit effects, Japan, two-stage budgeting procedure.

An increasing share of U.S. produced cigarettes has entered export markets over the last fifteen to twenty years (*Tobacco Quart.*). Although share increases have taken place, few empirical estimates of the demand for cigarettes in major importing nations have been reported. A good example is the cigarette market in Japan. While imported cigarettes make up a relatively small proportion of total cigarettes sold in the Japanese domestic market, the share of the Japanese market held by U.S. cigarettes increased by nearly 200% between 1964 and 1983. U.S.-manufactured cigarettes dominate the imported cigarette market in Japan, holding over 90% of the imported market. Japan is one of the top five importers of cigarettes from the United States. (*Tobacco Quart.*). Japan consumes virtually all imported and domestically manufactured cigarettes within the country, exporting very few cigarettes. Imports of tobacco have also increased over time, with the share of tobacco which is imported increasing from less than 10% to over 30% between 1964 and 1983. Given the declines in per capita consumption of cigarettes in the United States and the increasing share of cigarettes exported to Japan, estimates of elasticities of Japanese cigarette demand are of importance to policy makers, as well as to the U.S. cigarette and tobacco industries.

Japanese trade policies regarding imports of cigarettes during the last twenty years primarily consisted of a series of import tariffs. Prior to 1987, imports of cigarettes into Japan had tariffs placed upon them. Excise taxes were placed on cigarettes sold in Japan, whether imported or domestic.

The objectives of this study are twofold. The first objective is to estimate demand elasticities for cigarettes in Japan. The second objective is to determine whether or not consumption habits for cigarettes in Japan exist. Given that Japanese cigarettes and cigarettes manufactured in the United States hold the predominant share of the market, cigarette consumption in Japan is disaggregated into Japanese cigarettes, cigarettes from the United States, and cigarettes from the rest-of-world. Disaggregating cigarettes by country of origin is not implausible, because Japanese cigarettes are considered lower quality than U.S. cigarettes (*Tobacco Reporter*).[1] A two-stage budgeting procedure is employed to test whether habit effects exist at the level of share of income spent on cigarettes, and whether they exist at the level of share of cigarette expenditures spent on U.S., rest-of-world, or Japanese cigarettes. The procedure also allows for estimation of demand elasticities for the three types of cigarettes.

Methodology

The elasticity of demand for U.S. cigarettes has been investigated in several studies, and these studies provide some basis of comparison. Lyon and Simon estimated an arc elasticity close to −.5 for cigarette demand in the United States.

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[1] One reason may be that the Japan Tobacco and Salt Public Corporation, the manufacturer of cigarettes in Japan, must purchase all of the domestic crop (Nath). The actual composition of Japanese cigarettes, in terms of domestic versus imported tobacco content, was not available. Very little tobacco is exported out of Japan; therefore, Japanese cigarettes likely contain Japanese tobacco.

Baltagi and Goel updated Lyon and Simon's quasi-experimental estimates, finding the elasticity had dropped between 1965 and 1983 to −.17. Other econometric studies have reported the own-price elasticity of demand for cigarettes in the United States at around −.5 (Fujii; Sumner and Wohlgenant; Lewit, Coate, and Grossman). Sumner and Alston estimated the U.S. domestic demand own price elasticity at about −.29. Fujii estimated cigarette demand in the United States and found lagged consumption to have a statistically significant influence upon current consumption.

This study employs a two-stage budgeting procedure to estimate demand elasticities. The two-stage procedure incorporates an almost ideal demand system (AIDS) to estimate the second stage.[2]

The AIDS model expresses w_i, the ith budget share, as

$$(1)\quad w_{i,t} = \alpha_i + \sum_j \tau_{ij} \ln p_{j,t} + \beta_i \ln(X/P)_t, \qquad \text{for all } i,\ t = 1 \ldots T,$$

where $w_{i,t}$ is the expenditure share of the ith commodity in period t, $p_{j,t}$ are prices in period t, X is the total expenditure on all commodities in the system, and P_t is a price index, such that

$$(2)\quad \ln P_t = \alpha_o + \sum_k \alpha_i \ln p_{k,t} + 1/2 \sum_k \sum_j \tau_{kj}^{*} \ln p_{k,t} \ln p_{j,t}.$$

In this study, $w_{i,t}$ represents the expenditure share on the ith type of cigarette, including U.S., rest-of-world, and Japanese cigarettes.

The index, P_t, may be replaced by a linear approximation in the form of a geometric index, P_t^*, to produce a linear approximation of the system (Deaton and Muellbauer 1980a). The index, P_t^*, is defined so

$$(3)\quad \ln P_t^* = \sum_k \bar{w}_k \ln p_k,$$

where $\bar{w}_k$ is the mean of the budget share. Therefore, the approximation of (1), is

$$(4)\quad w_{i,t} = \alpha_i^* + \sum_j \tau_{ij} \ln p_{j,t} + \beta_i \ln(X/P^*)_t.$$

Blanciforti, Green, and King call this model the "linear approximate almost ideal demand system".

Two recent studies incorporated dynamic adjustment into the AIDS model (Eales and Unnevehr; Blanciforti, Green, and King). Eales and Unnevehr use a set of first differenced share equations. However, this formulation is somewhat restrictive. Several general forms for the share equations are suggested by Blanciforti, Green, and King, with one including a lag of per capita consumption of the good in the share equation and another form including a lag of the share in the share equation. The latter may be expressed as

$$(5)\quad w_{i,t} = \alpha_i^* + \alpha_i^{**} w_{i,t-1} + \sum_j \tau_{ij} \ln p_{j,t} + \beta_i \Big\{ \ln X_t - \alpha_o - \sum_j (\alpha_k^* + \alpha_k^{**} \tau_{k,t-1}) \ln p_{k,t} + 1/2 \sum_k \sum_j \tau_{ij}^{*} \ln p_{i,t} \ln p_{j,t} \Big\}, \qquad \text{for all } i,\ t = 1 \ldots T,$$

where $w_{i,t-1}$ is the expenditure share of the ith commodity in period $t - 1$. Autocorrelation of the error terms from a static AIDS model may indicate some type of misspecification of the model. Blanciforti, Green, and King cite autocorrelation of the error terms of the share equations of a static AIDS model as evidence that a specification which incorporates habit effects may be needed.

When a one-period lag of the share is incorporated on the right-hand side of the share equations, the theoretical demand restrictions will hold only at local values of $w_{i,t-1}$ for the coefficients of the dynamic AIDS model (Blanciforti, Green, and King).

The formulas for expenditure and price elasticities are

$$(6)\quad \mu_i = 1 + \beta_i / w_i, \text{ and}$$

$$(7)\quad e_{ij} = w_i^{-1} \left[\tau_{ij} - \beta_i \left(\alpha_j + \sum_k \tau_{kj} \ln p_k \right) \right] - \delta_{ij},$$

[2] An alternative system which is commonly used is the Armington model. However, the Armington model imposes a severely restrictive set of assumptions, including separability among import sources (Alston et al.).

where δ_{ij} is the Kronecker delta. The estimates for β_i, α_j, τ_{ij}, and τ_{kj} can be obtained from the linear approximate model.

The first stage of the budgeting procedure is hypothesized to be

$$(8) \quad M_t = \Phi_0 + \Phi_1 M_{t-1} + \Phi_2 \ln P_t^* + \Phi_3 \ln Z_t + \Phi_4 \ln Y_t + \Phi_5 YR,$$

where M_t is the share of per capita income expended on all cigarettes in the system in period t, M_{t-1} is the expenditure share in period $t - 1$, P_t^* is as defined previously, Z_t is an index of prices of goods other than cigarettes which make up the consumer's budget, Y_t is per capita income in period t, and YR is a time trend to reflect changes in health concerns and tastes and preferences. Notably, the share of income spent on cigarettes is a function of last period's share. Therefore, (8) implies that adjustments in expenditure share on all cigarettes to changes in income and prices are only partial within one period. While (8) implies adjustment at the level of share of income expended on all cigarettes, (5) implies adjustment in cigarette expenditure shares between cigarette types. Hence, the effects of habit can be distinguished at two levels.

The elasticity of expenditures on all cigarettes with respect to income, Ω, is found by

$$(9) \quad \Omega = 1 + \Phi_4/M,$$

where Φ_4 is from (8) and M is the share of income expended on cigarettes.

Income elasticities for the different types of cigarettes can be found by

$$(10) \quad \theta_i = \mu_i \cdot \Omega,$$

where θ_i is the income elasticity for the ith type of cigarette, μ_i is the expenditure elasticity for the ith type of cigarette, and Ω is the elasticity of expenditures on all cigarettes with respect to income.

Data

Data were gathered for the years spanning 1964–83. The years beyond 1964 were chosen because they followed the Surgeon General's report on smoking and health (Pugh).[3] Data for some variables found in the *Japan Statistical Yearbook* (Japan) were not available beyond 1983. Data for prices and quantities of imported cigarettes were gathered from *Commodity Trade Statistics* (UN FAO). Retail prices were unavailable for imported cigarettes, so prices at import with import tariffs and excise taxes added were used as proxies. Therefore, prices of U.S. cigarettes and rest-of-world cigarettes may be understated from their retail values.

Information regarding tax and tariff rates on cigarettes were obtained from the Japanese Embassy. Exchange rates were found in *International Financial Statistics* (UN FAO). All other data was gathered from the *Japan Statistical Yearbook* (Japan). An index of consumer food prices was used for Zt.[4] The proxy for Japanese retail price of cigarettes was the Tokyo price of one of the top selling brands (*Tobacco Reporter*, Jan. 1980). All prices were converted to yen per pack and were deflated by the Japanese CPI, and consumption was in packs per person per year. The measure of income, Yt, was gross national product per person, in yen.

Estimation and Testing

The system of equations for the second stage, including share equations for Japanese cigarettes, U.S. cigarettes, and rest-of-world cigarettes, was estimated using a static AIDS model, with homogeneity and symmetry imposed. The static model was estimated using iterative seemingly unrelated regressions, which produces results equivalent to maximum likelihood (Kmenta). The error terms from the estimated equations contained no statistical evidence of serial correlation, suggesting that a dynamic formulation in the second stage was unnecessary. Furthermore, when lags of the budget shares were incorporated, none of the coefficients on the lags were significantly different from zero. Multicollinearity diagnostics showed no strong indication that the lagged shares introduced degrading collinearity into any of the equations. Also, when lagged per capita consumption of each of the types of cigarettes was introduced as the measure of habit formation, negative serial correlation was introduced into the residuals from each of the equations indicating misspecification of the model. The estimated model is shown in table 1. All of the coefficients were signifi-

[3] Although Japan has fewer restrictions than the U.S. toward use of smokables, the Surgeon General's report was followed by large increases in imports of lower nicotine tobacco versus higher nicotine tobacco (*Tobacco Reporter*, Jan. 1980).

[4] Because an index for prices of consumer goods other than cigarettes was not available, a price index of a commodity group which makes up a large portion of the consumer's budget, food, was used. This implies the assumption that the commodity groups of cigarettes and food are separable.

Table 1. The Demand System for Cigarettes in Japan

	Estimated Coefficients						
Cigarette Group i	a_i	β_i	τ_{i1}	τ_{i2}	τ_{i3}	R^2	Durbin-Watson d
(1) U.S. cigarettes	−.2268	.0514	−.0040	.0093	−.0053	.8143	1.645
	[.0440][a]	[.0087]	[.0043]	[.0021]	[.0045]		
	(−5.154)[b]	(5.908)	(−.930)	(4.428)	(−1.177)		
(2) Rest-of-world cigarettes	.0406	−.0082	.0093	−.0055	−.0038	.8407	1.761
	[.0188]	[.0038]	[.0021]	[.0021]	[.0017]		
	(2.159)	(−2.157)	(4.358)	(2.619)	(−2.235)		
(3) Japanese cigarettes	1.1862	−.0432	−.0053	−.0038	.0091	.5636	1.608
	[.0500]	[.0097]	[.0045]	[.0017]	[.0055]		
	(23.724)	(−4.453)	(−1.177)	(−2.235)	(1.654)		

[a] Bracketed values are the estimated standard errors of the coefficients.
[b] Values in the parentheses are the t-statistics.

cantly different from zero at the .10 level except for the U.S. and Japanese cross-price coefficients and the coefficient on own-price in the U.S. and Japanese equations.[5]

The estimated equation for the first stage is

(11)

$$
\begin{array}{llll}
M_t = & -.33198 & +\ .22452\, M_{t-1} & +\ .00698 \ln P_t^* \\
 & [.07836] & [.05964] & [.00070] \\
 & (-4.327) & (3.764) & (9.997) \\
 + & .015124 \ln Z_t & -\ .00986 \ln Y_t & +\ .00015\, YR \\
 & [.00505] & [.00091] & [.00003] \\
 & (2.989) & (-10.759) & (5.221)
\end{array}
$$

$$R^2 = .9969 \quad \text{Durbin } h = .8751.$$

The coefficient on the lagged expenditure share was significantly different from zero, and at .22452 indicated an adjustment coefficient of .77548. The hypothesis that the adjustment coefficient was equal to zero was rejected. The coefficient on income also was significantly different from zero and had a negative sign. Using the estimated coefficient on the logarithm of income in equation (11) and the average budget share of cigarettes, the estimate for the elasticity of cigarette expenditures with respect to income is .1682. The elasticities of cigarettes with respect to income and with respect to cigarette expenditures are presented in table 2. The income elasticities for U.S. and Japanese cigarettes were positive, while the income elasticity for rest-of-world cigarettes was negative.

The own-price elasticities, also presented in table 2, were of the expected sign for all equations. The own-price elasticity for U.S. cigarettes was much less than that for Japanese cigarettes or rest-of-world cigarettes. The own-price elasticity on U.S. cigarettes sold in Japan is fairly similar to values which have been estimated for the own-price elasticity in the U.S.

As shown in table 2, positive cross-price elasticities indicated that Japanese and rest-of-world cigarettes were substitutes. They also indicated that U.S. and rest-of-world cigarettes were substitutes. The cross-price elasticities between cigarettes from the United States and Japan had a negative sign suggesting complementarity.

Conclusions

The elasticities suggest that U.S. and Japanese cigarettes may be considered normal goods, with U.S. cigarettes having a greater elasticity with respect to income than Japanese cigarettes. However, rest-of-world cigarettes are inferior goods. The elasticity estimates also imply that Japanese and rest-of-world cigarettes are substitutes. The own-price elasticities point towards more price responsiveness of consumption of rest-of-world cigarettes and Japanese cigarettes than of consumption of U.S. cigarettes.

The negative signs on the cross-price elasticities between U.S. and Japanese cigarettes are puzzling, particularly in light of the fact that the signs and magnitudes of the other elasticities seem plausible. The signs on the cross-price elasticities may perhaps indicate problems with the specification used. Pitts and Herlihy suggest that where there is a fairly fixed expenditure for a commodity group, or fixed volume of consumption, and the absolute values of the own-price elasticities are less than one, perverse sub-

[5] Because insignificant coefficients occurred, multicollinearity diagnostics were performed on all three equations. No strong evidence of degrading collinearity was found for any of the three equations.

Table 2. Elasticities of Demand for Cigarettes in Japan

Cigarette Group i	Income (θ_i)	Expenditure on Cigarettes (μ_i)	Uncompensated Price of Group i with Respect to Group j (e_{ij}) U.S.	Rest-of-World	Japanese
(1) U.S. cigarettes	.5950	3.5380	−.5631[a]	.3517	−2.9541
(2) Rest-of-world cigarettes	−.0432	−.2569	1.2130	−1.7902	.8806
(3) Japanese cigarettes	.1607	.9556	−.0076	.0019	−.9483

[a] All elasticities were calculated using only coefficients which were significantly from zero at the .10 level.

stitution relationships may result between commodities in the group.[6]

No habit effects could be found at the level of expenditure shares between types of cigarettes, implying that consumers adjust their expenditure shares completely in one time period to changes in prices and income. Habit effects could, however, be seen at the level of share of income spent on cigarettes. This suggests that, while consumers have little habit formation between the types of cigarettes, there is significant formation of habits in regards to total expenditures on cigarettes. These findings imply that, while Japanese consumers have not developed a habit formation for U.S. cigarettes, as compared with other types, neither have they developed habits specifically for Japanese cigarettes.

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[6] They hypothesize that when the absolute values of own-price elasticities of the goods are less than one and the expenditures on the commodity group are fairly fixed, as the price of one of the goods goes up the consumer may decrease the consumption of both.

Quasi-Experimental Price Elasticity of Liquor Demand in the United States: 1960–83

Badi H. Baltagi and Rajeev K. Goel

This paper uses sixty-five recent tax changes on liquor in private licensed states over the period 1960–83 to update Simon's quasi-experimental price elasticity of liquor. Three alternative measures for liquor price are used, and the sensitivity of this price elasticity to border effect purchases as well as market changes over time are examined. Our results support a liquor price elasticity estimate of −.7. However, the confidence interval on this estimate is wide. Border effect purchases as well as changes in the liquor market over time are statistically insignificant.

Key words: bootlegging, liquor demand, quasi-experimental price elasticity.

The price elasticity of liquor demand is important for policy makers trying to assess the effect of a change in liquor taxes on tax revenues. [Distilled Spirits Council (DISCUS) estimates the federal, state, and local revenues from distilled spirits to be $6.9 billion in 1983, 14% higher than in 1973, and nearly twice as much as in 1963.] This liquor price elasticity is also important for the liquor industry in determining the effect of a new tax on industry sales and profits. [The Liquor Handbook (Jobson Associates) reports that 157.4 million cases of distilled spirits were sold in the U.S. in 1983, and the Brewer's Almanac reports a 1.84 gallons per person consumption of distilled spirits in the U.S. for 1983.] Furthermore, this price elasticity can be used for studying public health issues as well as criminal activity related to alcohol consumption. In fact, Cook used this price elasticity to determine the effectiveness of liquor taxes in reducing consumption of liquor- and alcohol-related deaths, like auto fatality rates and cirrhosis of the liver.

One approach to estimating this price elasticity involves the specification and estimation of demand for liquor (see McGuinness for an econometric analysis of liquid demand in the United Kingdom; Clements and Johnson for Australia; Johnson and Oksanen 1974, 1977 for Canada; Niskanen; Wales, Smith, and Cook and Tauchen for the United States). Estimates of the price elasticity of liquor for the United States from this approach range from −2.03 by Niskanen to 0.08 by Wales, (see Ornstein for a survey). Alternatively, one can apply Simon's (1966b) quasi-experimental method to estimate this price elasticity. This method is well suited for commodities that have fairly constant prices that change only due to a tax change. It does not require the specification of a demand function and, because it is tailored around a tax change, the price elasticity is computed over a well-defined period. This approach yields a liquor price elasticity of −.79 for the period 1950–61. Since then, the period 1961–82 brought about an additional sixty-five tax changes on liquor in private licensed states.

This paper uses these tax changes to update Simon's quasi-experimental price elasticity of liquor over this recent period. This paper also checks the sensitivity of this elasticity estimate to alternative measures of liquor price and border effect purchases.

Methodology and Results

Simon (1966b) proposed the following price elasticity computation for each trial state that

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experienced a tax change:

$$\varepsilon_p = \left[\{(Q_2 - Q_1)/Q_1\} - \left\{ \sum_{i=1}^{n} (Q_{2i}^* - Q_{1i}^*)/Q_{1i}^* \right\} \Big/ n \right] \div \{(P_2 - P_1)/P_1\},$$

where P_1 and Q_1 denote the price and per capita consumption for the year ending before the tax change in the trial state. For liquor, Simon suggests leaving a period of three months before and five months after the price change to avoid the stock-up and liquidation effects that are associated with a tax change. P_2 and Q_2 denote price and per capita consumption for the year beginning after the tax change in the trial state. Q_{1i}^* and Q_{2i}^* denote per capita consumption for the relevant before and after periods for the ith comparison state, $i = 1, 2, \ldots, n$. A comparison state is any state where price did not change during the relevant period.

Simon (1966b) calculated the price elasticity of liquor using twenty-three price changes over the period 1950–1961. These price changes occurred in private licensed as well as monopoly states. Private licensed states denote states with privately owned liquor stores that are licensed by the state. Monopoly states have a legal monopoly on the wholesale or retail of liquor. For more on the effects of the two governmental systems on prices, revenues and consumption of liquor, see Simon (1966a). The median price elasticity reported is −.79 with a 96.5% confidence interval of (−.97, −.03). These calculations excluded the moonshine states, the District of Columbia, and two anomalous states that were not identified. In addition, Simon (1966b; p. 196) excluded price changes that are less than 2%.

In updating this elasticity, we consider sixty-five tax changes that occurred in private licensed states between 1961 and 1982. These are reported in the Distilled Spirits Council of the United States. Over this period the federal excise tax on liquor was constant at $10.50 (per proof gallon). The federal excise tax on liquor was raised to $12.50 per proof gallon on 1 October 1985. Simon (1966b, p. 196) suggests excluding price change events that occur within eighteen months before or after a federal tax change. Data availability together with the discontinuity introduced by a federal tax change forced us to restrict our sample until 1983. We also excluded all price changes that were less than 2%, the moonshine states, the monopoly states and the District of Columbia.

Consumption data for liquor (in gallons per capita) for each state are available from various issues of the *Brewers Almanac*. These data have been criticized on grounds that they are based on reports of wholesalers to the tax authorities. This consumption may differ from actual consumption because of moonshine activities in that state, underreporting by wholesalers to reduce their taxes, and border effects purchases, where commuters buy from an adjacent state with lower prices (Cook, Wales, Smith). Carlson (p. 31) reports that "about 55% of New Hampshire's $155 million in annual liquor sales is to out-of-state tipplers." Although we are unable to account for the underreporting phenomenon, we do exclude the moonshine states and vary the comparison states to deal with the border effects. This is done by excluding from the comparison group all states that are neighboring a state with a tax change. Removing these neighboring states should reduce the border effect bias, (Baltagi and Goel).

The data on the price of liquor are harder to find than the data on quantity. Simon (1966b, p. 197) used the price of Seagram 7 Crown because it is the largest selling brand and because it "is commonly used as a standard in the liquor industry." Data on this and eight other leading brands are available from yearly issues of the *Liquor Handbook* (Jobson Associates). These nine leading brands are Blend (Seagram 7 Crown), Straight (Old Crow), Bond (Old Forester), Scotch (Haig & Haig), Canadian (Seagram V.O.), Gin (Gordon's), Rum (Bacardi), Brandy (Christian Brothers), and Vodka (Smirnoff 80°). Three alternative measures for the price of liquor were used in this study: (*a*) the retail price of a fifth of Seagram 7 Crown; (*b*) a Laspeyres price index based on all nine brands with the quantities sold of each brand in 1972 serving as the base quantities; (*c*) a Paasche price index based on all nine brands with the prices of each brand in 1972 serving as the base prices. If some of the prices or quantities were missing, these indices were computed for all available brands. In fact, in all but seven cases these indices were based on five or more brands.

Table 1, panel A, gives the quasi-experimental price elasticity of demand based on these three measures for the price of liquor. The median price elasticity based on Seagram 7 Crown is −.924 compared with −.744 for the Paasche index and −.771 for the Laspeyres index. These elasticities are based on 35, 48, and 47 observations, respectively. This disparity in the number of observations is the result of missing data. Al-

Table 1. Quasi-Experimental Price Elasticities of Liquor Demand with and without Correction for the Border Effects: 1960–82

Price Measure:	Seagram 7 Crown	Paasche	Laspeyres
A. No correction for border effects			
Median	−.924	−.744	−.771
95% C.I. for the median[a]	(−1.160, −.602)	(−1.133, −.386)	(−1.249, −.503)
n	35	48	47
B. Corrected for border effects			
Median	−.779	−.616	−.629
95% C.I. for the median[a]	(−1.171, −.613)	(−1.214, −.166)	(−1.228, −.256)
n	35	48	47

[a] This confidence level is slightly larger than 95%, depending on the sample size; see Nair. For example, when n = 47, this is a 96% confidence interval.

though the latter two elasticities are lower than the Seagram 7 Crown elasticity, we fail to reject the fact that they are not significantly different from each other. A paired t-test was computed for the Seagram 7 Crown elasticity and the Paasche elasticity. The observed t-statistic is −.11, which is not statistically significant. Similarly, the paired t-test for the Seagram 7 Crown elasticity and the Laspeyres elasticity turns out to be −.35, which is again not statistically significant. Our Seagram 7 price elasticity of −0.924 for 1960–82 is higher than −0.79 reported by Simon for 1950–61. Some explanations for this increase in elasticity in recent years include greater health consciousness, health warnings, and education programs by organizations such as Mothers Against Drunk Driving. However, Simon's −.79 price-elasticity falls in the confidence interval reported in table 1 and our −.92 price-elasticity estimate falls in Simon's confidence interval. Also, Simon's −.79 estimate is not much different from the Paasche and Laspeyres elasticities.

Next, the sensitivity of this elasticity to the 'border effect' problem is considered. Table 1, panel B, calculates the same elasticities as in panel A; the only difference is a change in the comparison group. In fact, the new comparison group excludes all states that are neighboring any state with a tax change. The median price elasticities for the no neighbors comparison group are −.779, −.616, and −.629 for the Seagram 7 Crown, the Paasche, and the Laspeyres price elasticities, respectively. These border effect corrected elasticities are smaller than the corresponding ones obtained without this correction. However, this difference is not statistically significant. A paired t-test for the Seagram 7 Crown price elasticity with and without the neighboring states in the comparison group, yields an observed t-value of −.49 which is not statistically significant at the 5% level. Similarly, the Paasche and Laspeyres paired t-tests yield t-values of −.61 and −1.03, respectively. These results suggest that correcting for the border effect reduces the price elasticities. However, these reductions are not statistically significant.

Finally, we check the sensitivity of these elasticities to changes in the market over time. The observation period is split into two parts: 1960–69 and 1970–82. The results indicate lower price elasticities for the second period for all price measures considered. However, this difference is not statistically significant. (These are available upon request from the authors.)

Conclusion

This paper updated Simon's (1966b) price elasticity for liquor demand for the period 1960–83. This price elasticity was lower when a Paasche or Laspeyres price index was used instead of the retail price of Seagram 7 Crown (−.74 and −.77 compared to −.92). However, this difference was not statistically significant. These elasticities were also reduced by correcting for the border effect bias (−.62, −.63, and −.78, respectively). Again, this reduction was statistically insignificant. The lack of statistical significance for the liquor price elasticity with respect to border effect purchases is contrasted with an opposite occurrence for cigarette demand where the border effect was significant (Baltagi and Goel). A liquor price elasticity of about −.7 is supported by our results, even though the confidence interval is wide. This means that there is room for raising revenues by taxing liquor, but the reduction in alcohol consumption is not certain since consumers may switch to wine or beer.

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Whither Armington Trade Models?

Julian M. Alston, Colin A. Carter, Richard Green, and Daniel Pick

The Armington trade model distinguishes commodities by country of origin, and import demand is determined in a separable two-step procedure. This framework has been applied to numerous international agricultural markets with the objective of modeling import demand. In addition, computable general equilibrium (CGE) models commonly employ the Armington formulation in the trade linkage equations.

The purpose of this paper is to test the Armington assumptions of homotheticity and separability with data from the international cotton and wheat markets. Both parametric and nonparametric tests were performed, and the empirical results reject the Armington assumptions. This has important implications for international trade modeling and CGE modeling.

Key words: Armington, cotton, homotheticity, nonparametric tests, separability, wheat.

The responsiveness of import demand to international price changes is an important topic in applied international agricultural trade research. Elasticities of import demand are used commonly to estimate the effects of trade barriers and to examine trade policy options. Interest in the topic was renewed during the 1985 debate over the U.S. Food Security Act. In fact, the price responsiveness of import demand for U.S. agricultural sales became the single most important issue in the policy debate (Thompson 1988). Ultimately, the U.S. government decided that the import demand for U.S. agricultural exports (such as cotton and wheat) was price responsive. Foreign import demand elasticities in excess of unity were then used to justify lowering U.S. loan rates (i.e., floor prices) in attempting to regain market shares in the international markets (FAPRI, Myers).

Empirical estimates of import demand elasticities are predicated on the specification chosen for the trade model. A number of different model specifications have appeared in the literature, and these are well documented in two separate surveys by Sarris (1981) and Thompson (1981). The Armington model is a popular specification. It is a disaggregate model which distinguishes commodities by country of origin with import demand determined in a separable two-step procedure. The Armington approach permits the calculation of cross-price elasticities between imports from all sources using estimates of the aggregate price elasticity of demand for imports, a single elasticity of substitution and trade shares. Ease of use and flexibility are two reasons why the Armington model has been applied so often to international agricultural markets. Of course, another important reason is that the Armington model often gives results which are judged to be successful because of both plausible parameter estimates and statistical significance.

The Armington approach has been applied to modeling agricultural trade by Abbott and Paarlberg; Babula; Figueroa and Webb; Grennes, Johnson, and Thursby; Johnson, Grennes and Thursby; Penson and Babula; Sarris (1983); Suryana; Webb et al. In addition, it has been accepted as the appropriate way in which to model trade flows in a computable general equilibrium (CGE) model (de Melo and Robinson 1981, 1985) and has been used extensively in CGE models of international trade in agricultural products (e.g., Adelman and Robinson).

The Armington model assumes that import demands are homothetic and separable among import sources. Thus, within a market, trade patterns change only with relative price changes, and the elasticities of substitution between all

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pairs of products (e.g., between United States and Canadian wheat) are identical and constant. These are strong restrictions on demand. In this paper we test these restrictions using data from the international cotton and wheat markets.

Three approaches are used in our empirical work. All three approaches test restrictions on a country's system of import demand equations for a product (cotton or wheat) from different sources. The maintained hypothesis is that imports of the product from different countries comprise a weakly separable group so that we are considering restrictions on the second stage of a two-stage budgeting process.

First, nonparametric methods (from Varian 1982, 1983) are used to test (*a*) whether the data are consistent with a stable system or well-behaved import demand equations and (*b*) whether Armington restrictions hold. This approach provides a complete test of the hypothesis in question with no additional assumptions concerning functional form (Varian 1983, p. 100). The principal drawback is the unknown power of the tests and the possibility of false rejections due to measurement error (Varian 1985, Chalfant and Alston).

Second, the Armington model is estimated and tested as a nested model defined by a set of parametric restrictions on a double-log import demand model incorporating the complete set of relative prices. This provides a direct test of the Armington model, but the drawback is that we are testing against an alternative that cannot be fully compatible with the adding-up restrictions from demand theory unless preferences are restricted to be homothetic (e.g., see Deaton and Muellbauer 1980b, pp. 17–18).

Our third approach follows Winters. The almost ideal demand system (AIDS) of Deaton and Muellbauer (1980a) is used to estimate the parameters of the import demand equations, and Armington restrictions are tested parametrically. As with the nonparametric approach, this approach tests necessary conditions for Armington restrictions to hold in a model in which other theoretical restrictions (symmetry and adding up) can be imposed; it does not test the complete set of restrictions (including functional forms for demand) that make up the Armington model. This approach avoids the drawbacks of the nonparametric approach (unknown power) and that of the direct approach with the ad hoc double-log model. However, it does involve the imposition of the AIDS functional form to be tested as a joint hypothesis with the Armington restrictions. That is, it tests whether import demand equations are separable and homothetic under the maintained hypothesis that they are of the AIDS form.

The three approaches are complementary. The alternate methods yield different results on particular restrictions, but we find that all three approaches comprehensively reject the Armington model. In every country each approach rejects the restrictions implied by the necessary conditions that the demand equations are both homothetic and separable. Thus, we conclude that the Armington trade model is inappropriate for cotton and wheat.

Two-Stage Theoretical Models

In general, a two-stage budgeting procedure assumes that consumers allocate their total expenditures in two stages (Deaton and Muellbauer 1980b). In the first stage, total expenditure is allocated over broad groups of goods, while in the second stage group expenditures are allocated over individual commodities. It is well known that weak separability of the direct utility function over broad groups of goods is a necessary and sufficient condition for the second stage of a two-stage budgeting procedure. However, weak separability imposes restrictions on consumer behavior. First, the marginal rate of substitution between two goods from the same group is independent of the consumption of goods in other groups. Second, the substitution effects between goods in different groups are limited. A price change of a commodity in one group affects the demand for a commodity in another group only through the group income effect. Third, separability implies a restrictive relationship between price and income effects. More specifically,

$$S_{ij} = \mu_{GH} \frac{\partial q_i}{\partial x} \cdot \frac{\partial q_j}{\partial x}, \tag{1}$$

where S_{ij} is the compensated cross-price effect, μ_{GH} is a constant depending on groups G and H, q_i and q_j are quantities of the ith and jth goods where i and j belong to different groups, and x is total expenditure.

In the context of a trade allocation model, the two-stage budgeting procedure can be explained as follows. In the first stage an importer's total imports of a particular commodity can be expressed as

$$M = M(Y, P, P_o, Z_1), \tag{2}$$

where M is total imports of the commodity (e.g., cotton), Y is the importer's national income; P is an index of the import price of cotton, P_o is a vector of the prices of all other goods, and Z_1 is a vector of other explanatory variables.

In the second stage, total imports of the commodity are divided up among the various suppliers of the product to yield

$$(3) \quad M_i = M_i(M, P_1, \ldots, P_n, Z_2), \qquad i = 1, \ldots, n,$$

where M_i represents the imports of cotton from country $i (i = 1, \ldots, n)$, P_j represents the import price of cotton supplied by the jth export nation and Z_2 is a vector of other exogenous variables.

How does Armington's model relate to the above two-stage budgeting procedure? The first two stages of Armington's framework are, in general, equivalent to those described above. That is, in the first stage the importer decides how much of a particular commodity to import [equation (2)]. In the second stage [equation (3)], given the total amount imported, the importer decides how much to import from each supplier. Thus, the implications of weak separability apply to the possible substitution effects among commodity groups. In addition, the Armington model uses a CES within-group specification. That is,

$$(4) \qquad w_i = b_i^{\sigma}\left(\frac{P_i}{P}\right)^{(1-\sigma)},$$

where w_i is the market share of imports from source i, b_i is a constant, P_i is the price of the commodity from the ith source, P is the import price index depending only on the within-group prices, and σ is the constant elasticity of substitution parameter. The CES specification implies weak separability between different import sources.[1]

Further, as is clear in the CES specification of equation (4), the Armington approach assumes homotheticity of the subutility or within-group utility functions. This implies that an importer's market shares are independent of group expenditures. Consequently, all expenditure elasticities within a group are equal and unitary and import market shares change only in response to relative price changes. Thus, the Armington framework implies that in the second stage (within-group allocations) market shares do not vary with expenditures and that different import sources are separable. To test the Armington model, we focus on the properties of the second stage and test the implied restrictions of homotheticity and separability.[2]

Data

Wheat imports were analyzed for five importing nations: China, Brazil, Egypt, U.S.S.R., and Japan. These countries accounted for approximately 51% of world wheat imports in 1984/85. Annual data for prices and trade flows were obtained from the International Wheat Council, *World Wheat Statistics*. Prices were FOB quotations, basis the exporting country.

The number of observations for each of the importing regions varied based on the availability of data and import developments for that particular country. For Japan, the estimation period covered the years 1960/61–1984/85. Brazil imports wheat from three sources: Argentina, Canada, and the United States. However, Brazil started importing wheat from Canada only in 1970/71, and therefore the estimation period for Brazil included the years 1970/71–1984/85. Egypt has three primary import sources: Australia, the EEC, and the United States. The data included the period 1971/72–1984/85. Imports of wheat by the Soviet Union varied dramatically over the years. The United States became a major source for the Soviets during the 1972/73 marketing year. Argentina, Australia, and the EEC became major wheat exporters to the Soviet Union during the early 1980s. Canada has been the only major foreign source of wheat supply to the Soviet Union since the 1960s, although the quantity imported varied considerably from year to year. The data used for the USSR included the period of 1972/73–1984/85. The same period of analysis was used for

[1] The Armington model imposes the CES functional form on equation (3). This is the typical approach followed by those who have estimated Armington models (e.g., Sarris; Grennes, Johnson, and Thursby; Abbott and Paarlberg; Figueroa and Webb), and it is addressed in this paper. Alternatively, others (e.g., Goddard) have modified the Armington model by using a different functional form. Goddard used a generalized Box-Cox functional form.

[2] These tests are conditional on some general assumptions. First, general separability assumptions are implicitly made in our approach. For example, both cotton and wheat are assumed weakly separable from all other commodities. In addition, leisure (labor supply decisions) is assumed separable from all other commodities, and our approach assumes intertemporal separability. In order to make consumer models tractable, these separability assumptions are frequently made. Finally, in every case, in order to make the models tractable, we abstract from the problem of aggregation over consumers and over different varieties of wheat and cotton. These general assumptions are usually made in applications of Armington models.

the People's Republic of China (PRC). Although Australia and Canada have been exporting wheat to the PRC since the 1960s, the United States did not export wheat to China until the early 1970s.

Cotton imports were analyzed for five leading importing nations: France, Italy, Japan, Taiwan, and Hong-Kong. In 1983/84 these five countries accounted for 37% of total cotton imports. Annual data for prices and trade flows were obtained from *World Cotton Statistics* published by the International Cotton Advisory Committee. Prices were c.i.f. Liverpool, England. As with wheat, the number of cotton observations varied for each importing region. For Italy, Hong Kong, and France, the time period studied was 1969/70–1983/84. Data for Japan and Taiwan were not available for 1983/84 and thus the equations were estimated using data from the 1969/70–1982/83 period.

Nonparametric Tests

The nonparametric approach to demand analysis uses the results of revealed preference analysis to derive algebraic conditions on demand functions (Varian 1983). These conditions are used to test for the compatibility of data with the existence of a utility function that "rationalizes the data," to use Varian's terminology. We can also test for the compatibility of data with the existence of a utility function that is homothetic, separable, or both homothetic and separable (as implied by the Armington model).

Varian spells out the relevant conditions succinctly. First, compatibility of the data with the existence of a utility function is necessary to conduct demand analysis and the required condition is that the data satisfy the generalized axiom of revealed preference (GARP). When this condition is not violated, the data are consistent with having been generated by the maximization of a utility function by a representative consumer.[3] Second, for data sets that satisfy GARP we can proceed to test compatibility of the data with restrictions on the utility function.

Satisfaction of the homothetic axiom or revealed preference (HARP) implies the existence of a homothetic utility function that rationalizes the data. Thus, to test the Armington restriction of homotheticity, we check whether the data satisfy HARP. A necessary condition for (weak) separability of a subgroup (of a group of goods that satisfies GARP) is that the subgroup also satisfies GARP. This is only a necessary condition, the sufficient conditions require that the data satisfy both GARP and the Afriat inequalities (Varian, p. 105); however, Barnett and Choi (also see Belongia and Chalfant) suggest that the use of the sufficient condition biases the nonparametric test towards rejection of separability. Thus, a conservative approach (erring in favor of the Armington model) is to use only the necessary conditions. Finally, for data that satisfy separability we can test for "homothetic separability," which holds when demands for goods within a separable group are homothetic.

Varian has developed computer programs to test these conditions. Our testing procedure uses these programs as follows. First, each data set is tested with GARP. Next, for data that satisfy GARP, we apply HARP to test for homotheticity, and we test for separability of each import source from the rest. Then, for any data set that satisfies all of these tests, the homothetic separability test is applied. Only sets of import data (prices and quantities by source) that satisfy all of these tests are completely compatible with the Armington assumptions.

The results of the nonparametric tests are summarized in table 1. First, most of the data sets satisfy GARP. The exceptions were Brazil's wheat imports, Hong Kong's cotton imports, and Taiwan's cotton imports. Of course, these violations might be due to measurement error. Following Chalfant and Alston, we checked to see how much of a measurement error would be needed to have caused the violations of GARP that we observed. In the case of Brazil's wheat, only a very small measurement error (about 1% of prices or quantities) in one year (1977/78) could have accounted for the violation. Similarly, a very small measurement error in 1983/84 may have caused the violation of GARP in the case of Hong Kong's cotton imports. In the case of Taiwan's cotton, larger measurement errors (say 5% in 1970/71 and in 1976/77) would be required to account for the violations.

To conduct other nonparametric tests using these data sets that violated GARP we eliminated one observation from the Brazilian wheat date (1977/78) and the Hong Kong cotton data (1977/78) and two observations from the Taiwanese cotton data (1970/71 and 1976/77). With these observations eliminated, the remaining data satisfy GARP. This procedure is justified if we believe the violations were caused by measure-

[3] Chalfant and Alston provide a more intuitive explanation of GARP which they use to test for structural change in demand for meats.

Table 1. Nonparametric Test Results

		Separability of Wheat Source Country[a]				
Importer	GARP[b]	Australia	Argentina	Canada	U.S.	EC
China	0	+[c]	+	+	+	
Brazil	2		+	−	−	
Egypt	0	+			−	+
USSR	0	−	−	+	+	+
Japan	0	+		+	+	

		Separability of Cotton Source Country								
Importer	GARP[b]	USSR	Egypt	Mexico	Turkey	Sudan	U.S.	Pakistan	Brazil	Nicaragua
Italy	0	−	−	−	+	+	+			
Hong Kong	2	−					+	+		
Taiwan	7			+			+		+	
France	0	+	+		+		−			
Japan	0	−	−				+			−

[a] The wheat sources are Australia, Argentina, Canada, the United States, and the European Community. The cotton sources are the Soviet Union (USSR), Egypt, Mexico, Turkey, Sudan, United States, Pakistan, Brazil, and Nicaragua.
[b] Entries under GARP denote the number of observations that violated the generalized axiom of revealed preference. Observations that caused the violations of GARP for those countries were deleted to allow tests for separability to be carried out. These were No. 7 (1977/78) for Brazil's wheat, No. 15 (1983/84) for Hong Kong's cotton, and No. 2 (1970/71) and No. 7 (1976/77) for Taiwan's cotton.
[c] Entries denoted "+" indicate that imports from that country are separable from imports from the alternative sources. Entries denoted "−" indicate that imports from that country are not separable from other sources. Blanks indicate that data were not available for that supplier.

ment errors. An alternative procedure would be to experiment with adjustments to the data until GARP was satisfied. To the extent that they satisfy GARP, we may treat imports as a separable group and proceed to test homotheticity and separability as within-group restrictions.[4]

The second test was for homotheticity. All ten of the data sets violated HARP at every observation. Thus, homotheticity is rejected for every system of import demand equations being studied.

Third, we tested for separability among import sources by excluding each source of imports in turn and testing whether the remaining sources make up a separable group by applying the necessary condition, GARP. In the case of China's wheat imports and Taiwan's cotton imports, separability was not rejected for any source country. However, for the other four wheat importers and the other four cotton importers, separability was rejected for one or more of the source countries. For example, for France's cotton imports, the United States was not separable from the other sources, although each of the other sources was separable from the group comprising the rest including the United States.

Finally, because all of the data violate HARP, the test for homothetic separability is redundant. None of the data satisfy the necessary conditions of the Armington model, homothetic separability.

Armington Estimates

Consider the following double-log specification of the "within-group" allocation of expenditures among n sources (i) of imports within a country:

$$\text{(5)} \quad \ln M_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln \frac{P_j}{P*} + \beta_i \ln \frac{M}{P*},$$

where M_i is the quantity imported from source i, P_j is the price of imports from source j, M is total expenditure on imports of the good from all sources, and $P*$ is Stone's (geometric) price index for imports of this good.

[4] The Armington model has been applied sometimes to a group comprising imports plus the domestically produced good (e.g., Grennes, Johnson, and Thursby). Alternatively, others have dealt only with import (excess) demand, without explicit treatment of domestic supply and demand (e.g., Sarris 1983). None of the importers studied in this paper produce significant amounts of cotton, but several of the wheat importing countries (especially the Soviet Union and China) produce most of the wheat that they consume. We are therefore assuming that domestic wheat is a differentiated product within the wheat group in these countries. The Armington restrictions imply that any subgroup is separable so that a test of Armington restrictions on a subgroup tests necessary conditions for the Armington model.

(6) $$\ln P^* = \sum_{k=1}^{n} w_k \ln P_k,$$

where w_k is the expenditure share of source k in total imports.[5]

This model is homogenous of degree zero in all prices and total expenditure. However, it is not possible in general to impose the theoretical restrictions of symmetry and adding up (e.g., see Deaton and Muellbauer 1980b). The Armington model of equation (4) is nested within this model under the restrictions that $\gamma_{ij} = 0 \ \forall \ j \neq i$ (i.e., weak separability means that only the own-price and group price are included), $\beta_i = 1 \ \forall \ i$ (demands are homothetic), and $\gamma_{ii} = \gamma_{jj} = -\sigma \ \forall \ i, j$ (i.e., equality of the own-price coefficients). Under these restrictions the system of demands does satisfy the theoretical restrictions of symmetry and adding up and $\gamma_{ii} = -\sigma$ is the elasticity of substitution for the system.

We estimated this model for the ten cotton or wheat importers and tested the Armington restrictions of separability ($\gamma_{ij} = 0 \ \forall \ j \neq i$), homotheticity ($\beta_i = 1 \ \forall \ i$), and equality of own-price coefficients ($\gamma_{ii} = \gamma_{jj} \ \forall \ i, j$). The estimates were obtained using iterative seemingly unrelated regressions (SUR) techniques and the parametric restrictions were tested using the likelihood ratio procedure for which the test statistic is

(7) $$2[\lambda_u - \lambda_r] \sim \chi^2(J),$$

where λ_u is the log-likelihood for the unrestricted model and λ_r is the log-likelihood for the model with J parametric restrictions imposed.[6]

The results of these estimations and tests are summarized in table 2. The Armington model seems to fit the data reasonably well, and the estimates are plausible with the exception of Egypt's wheat imports for which the elasticity of substitution is negative and significant.[7] Outcomes such as those in table 2 help to explain the popularity of the Armington approach. However, the Armington restrictions are comprehensively rejected with the chi-square tests. While homotheticity could not be rejected in four of the cases, separability, homothetic separability, and the Armington model were rejected in all ten cases. The full Armington restrictions were rejected in all ten cases when the models were corrected for first-order autocorrelation as well as in the seemingly unrelated regressions (SUR) estimation.

The drawback here is that the Armington model is rejected in favor of a model that we cannot require to satisfy the theoretical restrictions that we would like to impose (and which the nonparametric tests indicate can be imposed) on the data. These restrictions can be imposed in the AIDS model and separability and homotheticity restrictions can be tested subject to symmetry and adding up as maintained hypotheses.

AIDS Model Estimates

In an AIDS specification (Deaton and Muellbauer 1980a, b) of import demand, the budget share of imports from source i is given by

(8) $$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln(M/P), \quad i = 1, \ldots, n,$$

where the log of the price deflator is

(9) $$\ln P = \alpha_0 + \sum_k \alpha_k \ln p_k + \frac{1}{2} \sum_j \sum_k \gamma_{kj} \ln p_k \ln p_j,$$

where M is total expenditure on imports and p_j are prices of imports from source j. Adding up, homogeneity, and symmetry, respectively, require that

(10) $$\sum_i \alpha_i = 1, \sum_i \gamma_{ij} = 0 \text{ and } \sum_i \beta_i = 0; \quad \sum_j \gamma_{ij} = 0; \quad \text{and } \gamma_{ij} = \gamma_{ji}.$$

[5] Armington used a CES price index (see, also, Sarris 1983). However, he expressed the model in percentage change form which is equivalent to first differencing the logarithmic form. Taking first differences of equation (6) in the logarithms of prices (i.e., holding shares constant) results in the price index used by Armington.

[6] Autocorrelation was present in many of these models both with and without the Armington restrictions. While this does not lead to biased parameter estimates, it might lead to biased standard errors and biased test results. Given our nonparametric results, supporting the existence of a well-behaved static system of demand equations, it is probably appropriate to interpret this autocorrelation as evidence of model misspecification. In any event, our main results are not sensitive to autocorrelation corrections.

[7] This result could easily be rationalized as being caused by; for example, the extensive involvement of the Egyptian government in the wheat market. However, it does imply positive own-price elasticities of demand, a result that is not implied by the data alone because the data satisfy GARP.

Table 2. Armington Model Estimates for Wheat and Cotton

Commodity Importer[a]	Estimates[b] σ	R^2	χ^2 Statistics for Hypothesis Tests[c] S	H	H&S	Armington OLS	Auto[d]
Wheat							
Brazil	2.42	0.90	13.96*	7.56	20.28*	24.54*	30.60*
(n = 3)	(1.70)						
China	6.96*	0.55	29.30*	26.74*	55.90*	66.10*	101.64*
(n = 4)	(3.65)						
Egypt	−1.91*	0.98	19.62*	4.68	27.48*	33.60*	28.32*
(n = 3)	(−3.78)						
Japan	0.75*	0.99	40.52*	8.66*	76.76*	87.04*	74.88*
(n = 3)	(3.35)						
USSR	3.45*	0.97	89.30*	61.82*	138.24*	160.60*	227.64*
(n = 5)	(4.55)						
Cotton							
France	2.04*	0.88	51.86*	21.56*	78.06*	81.42*	102.36*
(n = 4)	(4.22)						
Hong Kong	4.10*	0.82	22.18*	6.28	29.58*	41.18*	47.02*
(n = 3)	(3.04)						
Italy	0.76*	0.95	163.22*	32.24*	166.28*	173.28*	230.18*
(n = 6)	(4.00)						
Japan	1.26*	0.95	54.80*	10.52*	63.22*	76.56*	72.16*
(n = 4)	(3.34)						
Taiwan	5.04*	0.96	20.98*	1.82	23.42*	30.24*	23.12*
(n = 3)	(6.85)						

[a] n is the number of import sources analyzed.
[b] These are SUR estimates from the model with the full set of Armington restrictions; t-values are in parentheses.
[c] These statistics refer to the restrictions $\gamma_{ij} = 0 \; \forall \, j \neq i$ (S = separability) and $\beta_i = 1 \; \forall \, i$ (H = homotheticity). H&S denotes the joint restriction of homothetic separability. "Armington" denotes the full set of Armington restrictions—homotheticity, separability, and equality ($\gamma_{ii} = \gamma_{ij} \; \forall \, i, j$). The degrees of freedom for the χ^2 equal the number of restrictions which are $n^2 - n$ (separability), n (homotheticity), n^2 (homothetic separability) and $n^2 + n - 1$ (Armington), where n is the number of import sources. * indicates significant at $p = 0.05$.
[d] Auto refers to results after correcting for first-order autocorrelation.

The aggregate price deflator in (9) can be approximated by Stone's index from equation (6).[8] Having made this substitution, the AIDS model is identical to the double-log specification in equation (5) except that expenditure shares replace logarithms of quantities as the dependent variables.

The test for homotheticity in the AIDS import share equations is equivalent to testing that all the β_i are zero. This implies that the import shares are independent of the total import level [see equation (8)]. To test for separability between import sources, we follow Winters and test whether the price from a particular import source contributes anything to the otherwise complete allocation model. This condition is a necessary consequence of separability. In general, one of the implications of separability over groups is that the within-group demand functions contain only prices of commodities within that group. Thus, for each import source we estimated an AIDS excluding it and then tested whether its price had any influence on the included import shares.[9]

The import demand models of equation (8) were estimated by iterative SUR techniques with symmetry and homogeneity restrictions imposed. Because of the adding-up condition, the contemporaneous covariance matrix is singular. Thus, the standard procedure of arbitrarily deleting an equation was employed. The iterative SUR estimators have the same asymptotic properties as maximum likelihood estimators. The

[8] For a discussion of the effects of this substitution on the properties of the subsequent estimators, see Blanciforti and Green. Green and Alston discuss implications for computation of elasticities.

[9] The spirit of this approach is directly analogous to that used in the nonparametric test for separability where we tested source-by-source whether the demand system was sensitive to the exclusion of a source. This is a test of a necessary condition for the Armington model's assumption that all sources are separable. It is not as strong as the condition that all sources be jointly separable which is required by the Armington model.

Table 3. AIDS Model Test Results for Japanese Wheat Imports

	Homotheticity	Separability	Homotheticity and Separability
Separable Country (i)	$\beta_k = 0$	$\delta_{ki} = 0$	$\delta_{ki} = 0; \beta_k = 0$
	(t, d.f. = 21)	(t, d.f. = 21)	(F, d.f. = 2,21)
Canada	−0.79	1.47	1.08
Australia	−6.94*	2.01	32.36*
U.S.	4.15*	−0.86	10.08*
Complete system	$\chi^2(2)$ = 37.23*		

Notes: The critical values of these statistics for $p = 0.05$ are $t_{21} = 2.08$, $F_{2,21} = 3.47$, $\chi^2_2 = 5.99$. Asterisk denotes significance at $p = 0.05$. The F-test statistic is calculated as:

$$\frac{\left[\dfrac{SSE_u - SSE_r}{J}\right]}{\left[\dfrac{SSE_u}{N-K}\right]} \sim F_{J,N-K},$$

where N is the number of observations, K is the number of parameters being estimated in the unrestricted model ($K = 5$), J is the number of restrictions being tested ($J = 2$), SSE_u and SSE_r are the sums of squares of residuals from the unrestricted and restricted models, respectively (e.g., see Judge et al.).

estimates are invariant to the equation deleted (Barten). Because the primary focus of the paper is to examine the usefulness of the Armington model, only the tests of separability and homotheticity are reported.

In half of the cases analyzed imports are supplied by only three sources (wheat into Brazil, Egypt, and Japan and cotton into Hong Kong and Taiwan). In these cases, when we exclude one source to test for separability and then delete a further equation for estimation because of the singular residual covariance matrix, a single equation model remains to be estimated by OLS. The single equation for the expenditure share of imports from source k represents the demand for imports from two sources (k and j) as a function of their prices and total expenditure on imports from the two sources. To test for separability of a third source (i), we use a t-test on the coefficient of the logarithm of the price of imports from that source (δ_{ki}) in the share equation for source k. To test homotheticity in the reduced model (including only two of three sources), we use a t-test on the coefficient of the logarithm of real expenditures in the share equation of source k (β_k). To test the joint restriction of separability of source i and homotheticity within the reduced model ($\delta_{ki} = 0$ and $\beta_k = 0$), we use a standard F-test. In all cases a system of equations was estimated to obtain unrestricted estimates, and to test for homotheticity alone, using iterative SUR. In these multiple equation models, we use likelihood ratio tests of the various parametric restrictions implied by homotheticity, separability, or homotheticity and separability. The test statistic is the chi-square defined in equation (7).

In the interests of brevity, not all of the test statistics are reported here. Instead, only the values for Japan are reported in detail and those for all other importers are tabulated and reported in summary form. All of the values for all countries are available from the authors. Japan was singled out because it is a major importer of both cotton and wheat. Tables 3 and 4 report the detailed Japanese test results for wheat and cotton, respectively. In every case, the first column of each table contains the import source which is being tested to determine whether it is separable from the other (included) import sources.

First, consider the homotheticity constraint. Initially we test this restriction alone without any separability restrictions on sources of imports within the group. The last entry in the second column of tables 3 and 4 reports the test statistic. For Japan the restriction is rejected for both wheat and cotton in the full model including all sources. Consider tables 5 and 6 which summarize results for all countries. In the last column of table 5 (for wheat) it can be seen that homotheticity is rejected at the 5% level of significance in two countries (Japan and USSR) and is not rejected for the others (China, Brazil, and Egypt) when all sources are included. The homotheticity constraint in cotton (see table 6) is not rejected in Taiwan and Italy but is rejected for the other three countries (Hong Kong, France, and Japan). The other entries under "homo-

Table 4. AIDS Model χ^2 Test Results for Japanese Cotton Imports

	Homotheticity	Separability	Homotheticity and Separability
Separable Country (i)	$\beta_k = 0\ \forall_k$	$\delta_{ki} = 0\ \forall_k$	$\delta_{ki} = 0$ and $\beta_k = 0\ \forall_k$
	(d.f. = 2)	(d.f. = 2)	(d.f. = 4)
Egypt	2.12	6.74*	19.60*
Nicaragua	8.76*	16.26*	17.84*
USSR	4.34	8.54*	20.28*
U.S.	5.14	11.34*	17.24*
Complete system	$\chi^2(3) = 10.70$*		

Notes: The critical values of the χ^2 distribution for $p = 0.05$ are 5.99 (d.f. = 2), 7.81 (d.f. = 3), and 9.49 (d.f. = 4); asterisk denotes significance at $p = 0.05$.

theticity" in tables 3, 4, 5, and 6 refer to tests for homotheticity within a reduced model where one of the sources has been excluded to test for separability. This restriction is rejected in two of three cases for Japanese wheat imports (table 3) and one of three cases for Japanese cotton imports (table 4). Looking at all of the countries studied, the restriction is rejected in twelve of eighteen cases for wheat (table 5) and five of twenty cases for cotton (table 6).

With respect to separability over import sources, consider the third column in tables 3 and 4. The coefficient, δ_{ki}, is the log price coefficient on the import source (i) being tested in the share equation for an included source (k). For each import source being tested, the AIDS was estimated excluding it and then tested to determine whether its price had any influence on the remaining import shares. For Japanese wheat imports (table 3), in all three cases, separability is not rejected. For wheat in total (table 5), separability is rejected in nine of eighteen cases, in four of the five countries. Turning to cotton, separability was comprehensively rejected for Japanese imports (table 4). As shown in table 6, overall, separability was rejected in sixteen of twenty cases, and at least once in each of the five countries.

Finally, in the last column of tables 3 and 4, homotheticity and separability were tested jointly. The joint test is the critical test of the Armington assumptions. In every importing country these joint constraints were rejected at least once. In tables 5 and 6 it is found that the joint con-

Table 5. Summary of AIDS Significance Tests for Wheat

		Separable Country					
Importer	Test	Australia	Argentina	Canada	U.S.	EC	Complete System
China	*H*[a]	–	+	+	–		+
	S[b]	–	–	+	+		
	H&S[c]	–	–	+	–		
Brazil	*H*		–	+	–		+
	S		+	–	–		
	H&S		+	–	–		
Egypt	H	+			+	–	+
	S	+			–	+	
	H&S	+			–	–	
USSR	H	–	–	–	–	–	–
	S	–	–	–	+		
	H&S	–	–	–	–	–	
Japan	H	–		+	–		–
	S	+		+	+		
	H&S	–		+	–		

Notes: Statistical significance is measured at the 5% level, "+" indicates failure to reject the restriction, and "–" indicates the restriction is rejected. Blanks indicate the test was not applied to that source.

[a] Homotheticity.

[b] Separability.

[c] Homotheticity and Separability.

Table 6. Summary of AIDS Significance Tests for Cotton

Importer	Test	Separable Country: USSR	Egypt	Mexico	Turkey	Sudan	U.S.	Pakistan	Brazil	Nicaragua	Complete System
Italy	H[a]	+	+	+	+	+	+				+
	S[b]	+	−	+	−	−	−				
	H&S[c]	−	−	+	−	−	−				
Hong Kong	H	+					+	−			−
	S	−					−	−			
	H&S	−					−	−			
Taiwan	H			+			−		+		+
	S			−			−		+		
	H&S			−			−		+		
France	H	+	−		+		−				−
	S	−	−		+		−				
	H&S	−	−		+		−				
Japan	H	+	+				+			−	−
	S	−	−				−			−	
	H&S	−	−				−			−	

Notes: Statistical significance is measured at the 5% level, "+" indicates failure to reject the restriction, and "−" indicates the restriction is rejected. Blanks indicate tests were not applied.
[a] Homotheticity.
[b] Separability.
[c] Homotheticity and Separability.

straints were rejected in fourteen of eighteen cases for wheat and in seventeen of twenty cases for cotton.

Synthesis of Results

Table 7 summarizes the results from the three alternative approaches to testing Armington restrictions on import demand equations for cotton and wheat. A plus indicates the restriction is not rejected, while a minus sign indicates the restriction is rejected. Homotheticity was rejected in ten of ten countries by the nonparametric method, six of ten countries in the double-log approach, and in five of ten countries using the AIDS model, twenty-one of thirty times in total. Separability was rejected in eight of ten countries using the nonparametric approach, all ten countries using the double-log model, and in nine of ten countries using the AIDS model. That is, the necessary conditions were rejected in twenty-seven out of thirty cases. These necessary conditions are relatively weak restrictions compared

Table 7. Summary of Nonparametric, Double-Log, and AIDS Model Test Results

		Homotheticity			Within-Group Separability			Homotheticity and Separability		
Commodity	Importer	1	2	3	1	2	3	1	2	3
Wheat	China	−	+	+	+	−	−	−	−	−
	Brazil	−	−	+	−	−	−	−	−	−
	Egypt	−	+	+	−	−	−	−	−	−
	USSR	−	−	−	−	−	−	−	−	−
	Japan	−	−	−	−	−	+	−	−	−
Cotton	Italy	−	−	+	−	−	−	−	−	−
	Hong Kong	−	+	−	−	−	−	−	−	−
	Taiwan	−	−	+	+	−	−	−	−	−
	France	−	−	−	−	−	−	−	−	−
	Japan	−	+	−	−	−	−	−	−	−

Notes: (1) Nonparametric, (2) Double-log, (3) AIDS; a "+" indicates the restriction is not rejected, and "−" indicates the restriction is rejected (at $p = 0.05$ for parametric tests).

Table 8. Uncompensated Own-Price Elasticities of Demand for Imports of U.S. Cotton

	Elasticities at Sample Means[a]		
Importer	Armington Model[b]	Double-log Model	AIDS Model
France	−1.85*	−10.39*	−8.75
	(−4.22)	(−2.55)	
Japan	−1.12*	−3.98*	−2.92
	(−3.34)	(−2.30)	
Italy	−0.82*	−0.37	−2.80
	(−4.00)	(−0.19)	
Hong Kong	−2.35*	−7.75*	−3.82
	(−3.04)	(−4.44)	
Taiwan	−1.76*	−11.26*	−1.40
	(−6.85)	(−7.89)	

Notes: All elasticities are uncompensated "within-group" measures for second-stage allocations.
[a] t-values are in parentheses; for the Armington model these are t-values for $\hat{\sigma}$ which apply if shares are treated as exogenous.
[b] Armington elasticities computed according to $n_{ij} = -(1 - w_{ij})\sigma_i - w_{ij}$ where i denotes the importing country and j denotes U.S.

to the Armington separability restrictions. In the nonparametric and AIDS tests, we consider whether each source in turn is separable from the rest. The Armington model requires that all sources of imports are jointly separable. This restriction was rejected in all countries using the double-log model.

The joint test of homotheticity and separability is the critical test of the Armington model. On this criterion the results are quite unequivocal. With all three approaches and in each country, the Armington restrictions were comprehensively rejected.

Implications

Armington model estimates are commonly used in counterfactual policy simulations. In such contexts, the acid test might not be whether the Armington restrictions are rejected by the data but, rather, whether the resulting elasticity estimates are significantly biased. That is, how important is the finding that Armington restrictions do not hold in terms of the practical problems for which the estimates are being made?

A partial answer to this question is possible. In the context of the double-log model, the application of the Armington separability restriction, when it is inappropriate, amounts to omitting relevant explanatory variables. The omitted explanatory variables are prices of substitutes which are likely to be positively correlated with the own-price variable that is included. When the omitted prices are prices of substitutes (positive cross-elasticities), the own-price parameter estimate will be positively biased so that the own-price elasticities will be underestimated (i.e., less negative).[10] This argument is relatively straightforward in the context of the double-log model about which our reservations have already been expressed. Intuitively, it would seem reasonable to extrapolate to other functional forms, but that might not be appropriate. To illustrate the potential importance of these specification biases, own-price elasticities for imports of U.S. cotton in the five countries were computed using the three models (Armington, double-log, and AIDS). The results are in table 8.

The Armington estimates are mostly smaller than both the double-log and AIDS estimates. One exception is Italy's elasticity of demand for U.S. cotton where the double-log estimate is not statistically significant. With this exception the Armington model estimates are less elastic than the double-log estimates. This result is consistent with the argument above about the consequences of omitting relevant explanatory variables. The other exception is Taiwan's imports of U.S. cotton where the Armington model resulted in a demand elasticity slightly more elastic than that from the AIDS, although both were much less elastic than the estimate from the double-log model. If the AIDS model represented truth, we would say that the Armington model understates the true elasticities substantially (say 50%) in most cases. If the double-log estimates were correct, the biases are more important.

[10] This point was first suggested to us by Mike Wohlgenant (personal communication). Kmenta (pp. 443–44) proves the relevant arguments about the effect of omitting relevant explanatory variables.

Conclusions

This paper tested the assumptions of the Armington trade model in the context of the international cotton and wheat markets. The Armington model is comprehensively rejected with data from the five leading importing countries for each good, using three alternative testing approaches. This leads us to conclude that the Armington restrictions should not be applied as a matter of course in the analysis of import demand for these goods. By analogy, doubt is raised as to whether the Armington restrictions are appropriate for other goods and in other applications such as CGE modeling. At a minimum, where possible, commodity trade data should be tested for consistency with the restrictions, perhaps using tests like those used in this study. In general, it will be desirable and appropriate to use a less severely restrictive set of assumptions about demand relationships than those of the Armington model.

The main advantage of the Armington approach is its parsimony with respect to parameters to be estimated while retaining compatibility with demand theory. This advantage is often important in international trade studies where data are very limited, but it comes at a cost. When the restrictions are inappropriate, the parameters will be biased, possibly in important ways. When we use a parametrically more generous specification (such as the AIDS model), we lose the main advantage of the Armington model in exchange for reducing the risk of this specification bias. At the same time, as occurred in our estimates, risk of getting wrong signs is increased. Clearly, given the nonparametric results that support the existence of a well-behaved system of demands, the AIDS model can be a misspecified model, too. And, as with the Armington approach, data limitations restrict the options for specification searches to find the true model. Our tests comprehensively reject the Armington model for cotton and wheat. This leads to concern that similar conclusions may apply to other trade models in the literature based upon (untested) Armington restrictions.

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The Elasticity of Export Demand for U.S. Cotton

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The conceptually relevant elasticity for policy analysis is the total export demand elasticity, which takes into account feedback effects of the U.S. price on other countries' prices. In this paper, a total export demand elasticity for U.S. cotton is estimated in an extended Armington framework. The results indicate that the export demand facing the United States is probably elastic; however, estimated total demand elasticities are considerably less elastic than the estimated direct demand elasticities, which do not account for feedback effects resulting from finite excess supply elasticities in the rest of the world.

Key words: cotton, export demand, total elasticity.

In designing agricultural policy, a knowledge of relevant elasticities is essential. Given the current economic climate characterized by volatile export markets and prices, the price elasticity of export demand has received considerable attention. Economists, however, have not reached a consensus about the magnitude of this parameter. In their review of studies of price elasticity of export demand for agricultural commodities, Gardiner and Dixit report seven estimates of the elasticity of export demand for U.S. cotton, ranging from −0.02 (Taylor and Collins) to −5.5 (Johnson). Because the policy recommendations based on the assumption of an elastic foreign demand could differ dramatically from those based on the assumption of inelastic foreign demand, further research in this area is warranted.

The objective of this paper is to develop estimates of the elasticity of foreign demand for U.S. cotton. The Armington approach was used to formulate models for estimation because it is simple to formulate, is a powerful method for modeling U.S. crop exports (Sarris 1981, Thompson), and had not been used extensively in modeling cotton trade. The study differs from previous works by extending the Armington framework to estimate "total" elasticities of demand, in which feedback effects of U.S. price on the price of other countries' cotton is taken into account. Results from this paper should be useful in estimating the elasticity of export demand for U.S. cotton and in demonstrating the importance of estimating "total" export demand elasticities.

Extended Armington Framework

Armington (1969a, b) developed a theory of international demand for commodities which are differentiated by kind and origin. In the Armington model, products are distinguished by kind of good (rice, cotton, wheat, etc.) and by place of origin. Thus, U.S. cotton and Mexican cotton would be two products in the cotton market.

The basic assumptions underlying the Armington framework are: (*a*) the marginal rate of substitution between any two products (e.g., U.S. cotton and Mexican cotton) is independent of the quantity of any other produce; (*b*) the elasticity of substitution between any two products in one market equals the elasticity of substitution between any two other cotton products in the same market; (*c*) the elasticity of substitu-

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tion between any two products in a given market is constant.[1]

Armington's assumptions imply that the product import demand functions for a given good can be written as

$$(1)\qquad X_{ij}/X_i = b_{ij}^{\sigma}\,(P_{ij}/P_i)^{-\sigma},$$

where X_{ij} is the quantity of cotton from country j consumed by country i, X_i is total cotton consumed by country i, P_{ij} is the price of cotton from country j in country i, P_i is a price index of cotton in country i, and σ is the elasticity of substitution between any two products in a given market. Country i's total demand for cotton depends on the price index of cotton, P_i, the prices of other goods, and total expenditure. This structure of demand implies that the direct price elasticities of demand in country i have the form:

$$(2)\qquad N_{ijj} = -(1 - S_{ij}) * \sigma_i + S_{ij} * \eta_i,$$

$$(3)\qquad N_{ijk} = S_{ik} * (\sigma_i + \eta_i), \quad k \neq j,$$

where N_{ijk} is the elasticity of demand for cotton from country j with respect to the price of cotton from country k, in country i; S_{ij} is the expenditure share of cotton from country j in country i; and η_i is the overall elasticity of demand for cotton in country i. It is worth noting here that the Armington model assumptions about substitution elasticities are stringent in that all own- and cross-price relationships may be derived from a knowledge of the elasticity of substitution and overall elasticity of demand for the product.

Export demand facing a particular country supplying the good, say the United States, can be obtained by horizontally summing all product import demand curves facing this country. This specification implies that the own-price elasticity of demand for exports from the jth country (N_j) is the share-weighted sum of the own-price elasticities of demand in all importing countries. That is,

$$(4)\qquad N_j = \Sigma_i(X_{ij}/X_j)N_{ijj},$$

where N_{ijj} is defined by (2), and X_j is total exports from country $j(X_j = \Sigma_i X_{ij})$.

Equation (2) has been used by a number of researchers to compute demand elasticity for differentiated products (Babula; Grennes, Johnson, and Thursby; Johnson, Grennes, and Thursby). However, it is not a total demand response elasticity in the sense of Buse because prices of other products are assumed to remain constant in response to a change in the price of the product from the exporting country in question. For a good such as cotton, the United States accounts for a significant portion of total world trade, so other product prices would not be expected to remain unchanged when the U.S. price changes. In the context of the Armington framework, the total own-price elasticity of demand for exports from the jth country (N_j^*) would equal

$$(5)\qquad N_j^* = \Sigma_i(X_{ij}/X_j) * \{N_{ijj} + \Sigma_k N_{ijk} * (d\ln P_{ik}/d\ln P_{ij})\},$$

where N_{ijk} is defined by (3) and $k \neq j$. This specification assumes prices of other goods (e.g., corn, wheat, manufactures) and incomes in the importing countries are unaffected by changes in the export price of cotton from country j.

Conceptually, equation (5) shows that the demand curve facing country j can shift in response to a change in product price. If the excess supply curve of country k is upward sloping, then its border price will rise (fall) in response to an increase in the price of product j when the two products are substitutes (complements). Accordingly, the export demand curve facing country j will shift to the left so that the total demand response curve, *mutatis mutandis* demand curve, will be steeper than the *ceteris paribus* demand curve (Buse). Although the total elasticity of demand can easily be developed in the Armington framework, this point has received inadequate attention in the literature.

The price effect described here is conceptually distinct from the price transmission elasticity, which measures the response of internal domestic prices to changes in border prices.[2] Here, the focus is on the response of one country's border price to another country's border price. In this study, export demand elasticities for U.S. cotton will be estimated using both equations (4) and (5) so that the significance of indirect price effects can be ascertained.

Estimation Approach

Although the Armington approach can be used to develop market-share equations that are linear

[1] To relax the restrictive assumptions of the CES functional form, a constant ratio elasticity of substitution homoethetic (CRESH) functional form can be used. Artus and Rhomberg were the first to use this specification of the Armington model. The application of the CRESH model is substantially more complicated than application of the CES function, however, and there is no conclusive evidence for its superiority (Deppler).

[2] Following Bredhal, Myers, and Collins, elasticities of price transmission for cotton are assumed to be either 1 or 0, depending on whether centrally planned countries are assumed to be price responsive.

in the parameters and relatively easy to estimate, there has been little effort made to estimate σ directly. Both Armington; and Grennes, Johnson, and Thursby assumed σ was equal to three, and then used equation (2) to calculate the direct elasticity of import demand. Given the importance of σ in determining the elasticity of export demand, this parameter will be estimated directly in this study.

The Armington approach is particularly well suited to estimate the elasticity of import demand for a particular region because a system of market share demand equations for the region can be estimated with σ held equal across equations. The constraint would assure that the assumption of equal elasticity of substitution between product pairs would not be violated.

To estimate the demand elasticity facing an exporter, however, this type of approach would be impractical because the number of equations to estimate would be equal to $N * M$, where N is the number of importing regions and M is the number of exporters. Fortunately, failure to estimate the entire set of market share equations jointly for each importer does not lead to biased estimate of σ for the region, although the variances of the single-equation estimates would be expected to be greater than those from pooled estimates.

For this study, countries were grouped into five regions: (*a*) Western European nations (Europe), (*b*) Japan, (*c*) other Asian importers (Asia), (*d*) centrally planned nations, and (*e*) Canada. The Western European region is composed of Austria, Belgium, Denmark, Finland, Germany, Ireland, Italy, Netherlands, Norway, Sweden, Switzerland, United Kingdom, Yugoslavia, Spain, and Greece. The centrally planned nations are the USSR, the P.R.C., and Eastern Europe. The Asian group consists of Hong Kong, Phillippines, Thailand, Malaysia, Republic of China, and Indonesia.[3] Although Korea is a major importer of U.S. cotton, trade arrangements have been such that Korea imports virtually all of its cotton from the United States. These trade arrangements also make it difficult to discover the "true" price of U.S. cotton in the Korean market; hence, Korea was not included in the Asian group.

Time-series data for the years 1959–83 were used in the estimations. Actual adjustments may not be instantaneous, and as Ayuk and Ruppel have pointed out, export shipments often lag sales contracts. Accordingly, following Nerlove, the partial adjustment framework was used to estimate import demand equations. In this framework, equation (1) can be expressed as

$$\text{(6)} \quad \ln(MS^d_{ij}) = \sigma^*\ln(b_{ij}) - \sigma^*\ln(P_{ij}/P_i),$$

where MS^d_{ij} is desired market share of imports from country j into country i, and σ^* is the long-run elasticity of substitution. The relationship between the actual and the desired market share is expressed as

$$\text{(7)} \quad \ln(MS_{ij}(t)) - \ln(MS_{ij}(t-1)) = \delta\{\ln(MS^d_{ij}(t)) - \ln(MS_{ij}(t-1))\},$$

where the coefficient δ is the adjustment coefficient, and t indicates the time period. Substituting (7) into (6) and rearranging leads to

$$\text{(8)} \quad \ln(MS_{ij}(t)) = \delta\sigma^*\ln(b_{ij}) - \delta\sigma^* \ln(P_{ij}/P_i) + (1-\delta)\ln(MS_{ij}(t-1)),$$

where $\delta\sigma^* = \sigma$ is the short-run elasticity of substitution. Note that the formulas in (2) and (3) can still be used to derive short-run, own-, and cross-price elasticities of demand. A long-run elasticity can also be developed from (8) by dividing the short-run elasticity by $1 - \delta$. The short-run elasticities are of the most interest here given the constantly changing world economic environment.

To account for possible changes over time that are unrelated to relative prices, a trend can also be included in the estimates. This specification of trend is similar to that employed by Sarris (1983). In our study, we assumed that the intercept, b_{ij} was a function of time (T), so that

$$\text{(9)} \quad b_{ij} = A_{ij}T^{\beta}_{ij}.$$

Substituting (9) into (8) leads to the functional form to be estimated.

The adjustment framework used here is similar to those used by Sirhan and Johnson in their study of cotton demand in selected European markets and by Chambers and Just in their study of the export demand for wheat. The primary difference in the studies is that we adhere to the Armington formulation of the price ratio, and, consequently, the Armington method of calculating elasticities is appropriate.

All data were obtained from various issues of *Cotton World Statistics*. U.S. cotton price is the CIF Liverpool price of S.M. 1–1/16 inch cotton. The world average price is a trade-weighted average of the U.S. cotton price and prices of

[3] Market share equations for individual countries within a region were also developed. Aggregation did not appear to have a noticeable effect on the estimates of σ. Individual country estimates are not reported because of space considerations but are available from the authors on request.

Table 1. Market Shares of U.S. Cotton in Foreign Markets (1959–83)

	Europe	Japan	Other Asia	Canada	Centrally Planned
Constant	−0.508	−0.951	−0.457	−0.133	−2.988
	(0.527)	(0.261)	(0.190)	(0.212)	(0.882)
Price ratio	−8.387	−3.119	−2.160	−4.898	−18.913
	(2.024)	(1.743)	(1.535)	(0.015)	(5.280)
MS_{t-1}	0.829	0.401	−0.041	0.370	0.335
	(0.187)	(0.123)	(0.168)	(0.143)	(0.133)
Trend	0.087	0.120	−0.097	0.009	0.549
	(0.224)	(0.081)	(0.069)	(0.080)	(0.272)
R^2	0.586	0.459	0.211	0.522	0.585

Note: Equations estimated in loglinear form. Numbers in parentheses are standard errors.

comparable quality cotton growths from Mexico, Brazil, Iran, the USSR, Turkey, and Syria.

Estimated Market Share Equations

Generalized least squares (GLS) estimates of the market share equations are reported in table 1. The GLS procedure was used to correct for autocorrelation in equations that tested positively for it and to account for contemporaneous correlation across equations using Parks procedure. Because the estimated equations contain a lagged dependent variable, to correct for autocorrelation it was necessary to first create an instrumental variable for the lagged dependent variables following the method suggested by Wallis. (The first-pass OLS equations did not differ markedly from the final estimates.) R^2 values reported in the tables are from prior stage estimates that have not yet been corrected for contemporaneous correlation.

Estimates of the elasticity of substitution range from a low of 2.16 in the Asian region to a high of 18.91 in the centrally planned region.[4] A lagged price ratio was used in the equation for the centrally planned nations. When current prices were used, the estimate of sigma was statistically insignificant at the 10% level.[5] Although the centrally planned nations, by definition, do not operate under the assumptions inherent in neoclassical microeconomic theory, it is reasonable to assume that they would be sensitive to the relative prices of the various cotton products once the import levels were determined. The appropriateness of including the centrally planned nations as import price sensitive should be explored further in future research.

In table 2, elasticity estimates are presented for three assumptions about the overall elasticity of demand for cotton (η_t). First, an upper bound of 0 (perfectly inelastic) and a lower bound of −1 (unitary elasticity) were assumed. Both intuition and empirical evidence suggest that total short-run demand for cotton fiber is inelastic. Spinning technology is largely fixed in the short run, limiting the substitution of other fibers (Jones-Russell). Additionally, the cost share of raw cotton in finished textile products is small (Wohlgenant). Total elasticities of demand, calculated from Babula's first-stage demand equations, ranged from −0.12 (Korea) to −0.257 (Japan). Monke and Taylor estimated a pooled short-run elasticity of demand of −0.24 for major cotton-consuming nations. Given the preponderance of evidence, we assumed first-stage demand to be inelastic, and 0 and −1 were chosen as probable bounds on the total elasticity. Two estimates of the elasticity of import demand for U.S. cotton were calculated by setting total elasticity equal to each of these boundary values. Finally, a third estimate of the export demand elasticity was calculated using the Monke and Taylor estimate of total demand elasticity (−0.24) in all regions.

Using equation (2) in equation (4), the direct elasticity of demand for U.S. exports, N_{us}, is expressed as

$$(10)\quad N_{us} = \Sigma_i\, x^i_{us}/X_{us}\,\{-\sigma^i(1 - S^i_{us}) + \eta_t S^i_{us}\},$$

where x^i_{us} is U.S. imports into country i, η_t is the total elasticity of demand for cotton (as-

[4] The five regional equations were also estimated without the adjustment framework. In four of the five regions, the absolute value of the price-ratio parameter increased, but only in Europe did it increase by a large percentage (−12.24 in the unadjusted model). The Japanese parameter decreased slightly in absolute value. R^2 values fell considerably in most cases.

[5] Ayuk and Ruppel found that the lag between contract and shipment can have a significant effect on estimates of the own-price effect. These countries may have a longer than average delay before shipments are made, causing the lagged price ratio to be more appropriate. This information is not in the general public domain, however, so this hypothesis would be difficult to test.

Table 2. Calculation of Elasticities from Aggregating into Regions

Region	Average U.S. Market Share 1977–82	σ	Average % all U.S. Exports 1977–82	$\eta_t = 0$	Elasticity $\eta_t = -.24$	$\eta_t = -1$
Europe[a]	.153	8.39	.110	−7.106	−7.143	−7.259
Asia[b]	.480	2.72	.266	−1.123	−1.238	−1.603
Japan	.426	3.12	.211	−1.790	−1.892	−2.216
Canada	.902	4.90	.035	−0.480	−0.696	−1.382
Centrally Planned Nations[c]	.239	18.91	.172	−14.391	−14.448	−14.630
1) Weighted average without Centrally Planned Nations			.582	−1.42	−1.50	−1.68
2) Weighted average with Centrally Planned Nations			.754[d]	−3.90	−3.97	−4.19

[a] Austria, Belgium, Denmark, Finland, Germany, Ireland, Italy, Netherlands, Norway, Sweden, Switzerland, U.K., Yugoslavia, Spain, and Greece.
[b] Japan, Hong Kong, Philippines, Thailand, Malaysia, Republic of China, and Indonesia.
[c] USSR, Eastern Europe, and People's Republic of China.
[d] Republic of Korea accounted for nearly all remaining cotton exports from U.S.

sumed equal across regions), X_{us} is total U.S. exports, and σ^i is the elasticity of substitution for cotton products in the ith region or country. Because the price of U.S. cotton historically has been quite close to the average price of cotton, the sales shares in equation (10) are approximated by quantity shares.

With the exception of Canada, there are no dramatic changes in N_{us} under the alternative assumption. When the centrally planned nations are excluded from the trade-weighted elasticity (i.e., when the elasticity of price transmission is set to zero for these countries), the upper bound estimate is -1.42 ($\eta_t = 0$) and the lower bound estimate is -1.68 ($\eta_t = -1$). Assuming an elasticity of price transmissions of 1.00 for the centrally planned nations brings the estimates of the trade-weighted elasticities to -3.90 ($\eta_t = 0$) and -4.19 ($\eta_t = -1$). Using Monke and Taylor's estimate of total demand elasticity results in a trade-weighted estimates of -1.50 for the assumption of nonprice-responsive centrally planned nations and -3.97 for the assumption of price-responsive centrally planned nations.

The estimates without the centrally planned countries are reasonably close to those calculated by Wohlgenant, and the estimates with the centrally planned nations are close to Johnson's calculated elasticity, which included these countries. It is clear from these calculations that relatively large changes in the overall elasticity of demand have only a small effect on the elasticity of demand for U.S. cotton. The inclusion or exclusion of the centrally planned nations is important, however.

Estimates of Total Export Demand Elasticities

The estimates developed in the preceding section are valid only if the price of cotton from other exporters will not change in response to a change in U.S. price. This condition implies a perfectly elastic export supply, an assumption that seems unrealistic. By its nature, the Armington model lends itself easily to the development of a far less restrictive model in which finite elasticities of export supply can be incorporated.

A simple static equilibrium model can be used to determine the change in competing product prices with respect to a change in the U.S. price. Let q_1 represent U.S. imports and q_2 represent imports from all other countries. Totally differentiating demand and supply yields

(11) $$d\ln q_1 = e_{11}\, d\ln P_1 + e_{12}\, d\ln P_2$$
(import demand for U.S. cotton)

(12) $$d\ln q_2 = e_{21}\, d\ln P_1 + e_{22}\, d\ln P_2$$
(import demand for other cotton)

(13) $$d\ln q_2 = E_s d\ln P_2$$
(export supply from ROW),

where e_{11} and e_{22} are direct own-price elasticities of demand for q_1 and q_2, respectively, e_{12} and e_{21} are the direct cross-price elasticities, E_s is the elasticity of export supply from competing suppliers, and ROW means rest of the world.

From (12) and (13), we obtain the impact of the U.S. border price on other countries' prices as

(14) $$d\ln P_2/d\ln P_1 = e_{21}/(E_s - e_{22}).$$

Substituting (14) into (11) and solving for $d\ln q_1/d\ln P_1$ yields the simplified expression for total demand response elasticity in (5) as

$$(15)\quad d\ln q_1/d\ln P_1 = e_{11} + e_{12} * e_{21}/(E_s - e_{22}).$$

For this aggregate model, consisting of the United States and the rest of the world, the counterparts to (2) and (3) are

$$e_{11} = -\sigma(1 - S_{us}) + \eta_t S_{us}$$

$$e_{12} = \sigma(1 - S_{us}) + \eta_t(1 - S_{us})$$

$$e_{21} = \sigma S_{us} + \eta_t S_{us}$$

$$e_{22} = -\sigma S_{us} + \eta_t(1 - S_{us}),$$

where σ is the aggregate elasticity of substitution between the United States and the ROW. Because regional estimates were used in these calculations, world-wide elasticities were derived by summing trade-weighted regional estimates. The trade weights are the percentages of total competing exports sent to each importing region.

Using regional estimates of σ leads to estimates of 2.22 for e_{21} and -2.46 for e_{22} when the centrally planned nations are assumed price responsive. If the centrally planned nations are considered nonresponsive, the estimates are .796 for e_{21} and $-.959$ for e_{22}.

An estimate of E_s can be obtained either by direct estimation or by using the excess supply specifications:

$$(16)\quad E_s = \Sigma_i e_{si}(Q_{xi}/Q_{si}) - \eta_{di}(Q_{xi}/Q_{di}),$$

where e_{si} is the domestic supply elasticity, Q_{xi} is quantity of exports from the *i*th country or region, Q_{si} is total supply in country i, N_{di} is domestic demand elasticity, and Q_{di} is domestic use. Using e_{si} of .38 and N_{di} of $-.24$ (Monke and Taylor) for the major price-responsive competing exporters and domestic elasticities of zero for the USSR yields an excess supply elasticity for U.S. competitors in the cotton market of 1.11.[6]

Using these elasticity estimates leads to a value for equation (14) of .62 when the centrally planned importing region is assumed price responsive, and .38 when the centrally planned importing region is assumed nonprice responsive. These, in turn, lead to estimates of the total elasticity of export demand of -1.62 (price-responsive centrally planned region) and -0.97 (non-price-responsive centrally planned region).

[6] The competing price-responsive exporters are Syria, Australia, Turkey, Israel, India, and the cotton-producing countries of South America, Central America, and Africa.

Conclusions

In this study, the usual Armington framework was extended to account for finite elasticities of export supply from U.S. competitors. The resulting "total" elasticities are more realistic for evaluating the effects of U.S. policy changes. Accounting for feedback effects of the U.S. price on other countries' cotton prices had a significant impact on the estimated export demand elasticity. Trade-weighted elasticities decline from about -4 to -1.6 when centrally planned importers are assumed price responsive, and from about -1.5 to -1.0 when centrally planned importers are assumed nonprice responsive.

Based on this work and the existing literature, it is highly probable that the direct elasticity of export demand for U.S. cotton is elastic. However, the total elasticity is considerably less elastic. Policy analysts should be aware that evaluating policy changes using only the direct elasticity may yield misleading results. For commodities such as cotton, for which the United States accounts for a large share of total world trade, the conceptually relevant elasticity for policy analysis is the total export demand elasticity; it takes into account the feedback effects of the U.S. price on other countries' prices.

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Alternative Estimates of Fed Beef Supply Response to Risk

Frances Antonovitz and Richard Green

Supply response models for fed beef incorporating risk by including both the mean and variance of output price are developed, estimated, and compared. Six different estimates of the mean and variance are obtained from futures prices; ARIMA processes; and naive, adaptive, and rational expectations models. Empirical estimates are compared using nonnested testing procedures and indicate that the choice of the expectations model significantly influences elasticity estimates and whether supply response is positive or negative. Empirical evidence does not support any one model in particular, suggesting that expectations are heterogenous rather than homogenous.

Key words: fed cattle, nonnested hypothesis testing, price expectations, risk, supply response.

Most agricultural production is characterized by a lag between the time input decisions are made and the time output actually reaches the market. As a result, supply response functions are based on the hypothesis that quantity produced depends on known input prices and producers' expectations of output price. Expectations frequently have been modeled based solely on past prices. Examples include naive expectations, adaptive expectations (extensively reviewed by Askari and Cummings), and autoregressive integrated moving-average (ARIMA) schemes. Gardner as well as others have used futures prices to estimate producers' expected prices, although Chavas, Pope, and Kao found that futures prices are not good proxies for producers' expectations in the presence of government programs. Furthermore, Muth's concept of rational expectations has also been empirically tested for agricultural commodities by Goodwin and Sheffrin, and Shonkwiler and Emerson. However, some authors have argued that ARIMA specifications are essentially equivalent to rational expectations and are empirically easier to implement (e.g., Feige and Pearce; Nerlove, Grether, and Carvalho). Others (e.g., Orazem and Miranowski, Shonkwiler and Hinckley) use futures prices as rational expectations.

Hence, there is diversity in the literature about the interpretation and estimation of rational expectations. In addition, evidence has supported heterogenous rather than homogenous expectations. That is, because market participants may form their expectations in different ways, the aggregate of these expectations is better characterized by a weighted average of a number of models rather than simply one model. Frankel and Froot find this to be the case for exchange rate expectations, and Shonkwiler and Hinckley for feeder cattle.

Most supply response models have focused on the mean of producers' subjective distribution (or the price expectation), excluding the variance and higher moments from the model. A few authors (Behrman; Just 1974, 1977; Traill; Lin; Ryan; Antonovitz and Roe 1986a, b) have introduced risk into their supply response functions, although each of these authors examines only one model of price expectations in the analysis. All of these studies find that the risk variables are important to some extent. Hence, empirical evidence suggests that risk should not be neglected in supply response, but exactly which model best reflects this risk component has not been the focus of any study.

The purpose of this paper is to develop, estimate, and compare a number of supply response models for fed beef that incorporate the

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mean and variance of the distribution of output price. Six different estimates of the mean and variance are obtained from the following models: futures price; ARIMA processes; and naive, adaptive, and rational expectations models. Empirical estimates of each are presented and compared using nonnested testing procedures.

The work in this paper makes a number of important contributions. The derivation and estimation of a supply response model including rational expectations of both the mean and variance are novel. In addition, the empirical results indicate that the choice of the expectations model is critical for fed beef and, hence, may be important for other commodities as well. Either a positive or a negative supply response may be observed depending on the choice of the expectations model, and elasticity estimates with respect to the mean and the variance may also be quite different.

The Model

Supply response for the United States fed cattle market will be modeled by specifying quantity as a linear function of input prices and the mean, variance, and higher moments of producers' expectations of output price. A theoretical justification for this model is provided by Roe and Antonovitz (1986a).

When feeder cattle are purchased by the feedlot operator, the sale price five to eight months later is not known.[1] Although the sale of futures contracts by feedlot operators could reduce this price risk, Antonovitz and Roe estimate that less than 2% of all cattle marketed are hedged in the futures market; thus, hedging is excluded from the analysis. Most enterprise costs are comprised of direct costs, especially feeder cattle and feed. Hence, feeder cattle and corn prices, which are assumed to be known when the feeder cattle are purchased, are the relevant input prices in the supply equation.[2] Any number of moments of producers' subjective distribution of fed cattle price could be used in specifying supply response; however, only the mean and variance are considered in this study. A bimonthly model (i.e., combining every two months) is formulated because it lends itself to estimation of the price expectations model.[3] Because fed cattle production has a distinct seasonal pattern with the heaviest placements in the fall months, bimonthly dummy variables were also included in the model. The aggregate supply function for fed cattle can be specified as

$$(1) \quad QCAT_t = \beta_o + \sum_{i=1}^{5} \beta_i S_{it} + \beta_6 PCN_{t-r} + \beta_7 PF_{t-r} + \beta_8 P_t^* + \beta_9 \sigma_t^* + \epsilon_t,$$

where S_{it} are bimonthly dummy variables to reflect seasonality; $QCAT_t$ is quantity of fed cattle marketed in bimonth t, total liveweight in million pounds; PCN_{t-r} is the average price of corn three to four bimonths prior to t, dollars per bushel; PF_{t-r} is the average price of feeder cattle three to four months prior to t, dollars per hundredweight; P_t^* is the fed cattle price expected in bimonth t formulated three to four bimonths prior to t, dollars per hundredweight; σ_t^* is the variance of fed cattle price expected in bimonth t formulated three to four bimonths prior to t, dollars squared per hundredweight squared; and ϵ_t is the error in bimonth t.

Seventy-four bimonthly observations from 1972 through the second bimonth of 1984 were used to estimate the functions. Supply was represented by fed cattle marketings in seven major cattle feeding states. Corn price was expressed as the price received by farmers in Iowa averaged three to four bimonths prior to t. Feeder cattle price was determined by averaging 400–500 pound (four bimonths prior to t) and 600–700 pound (three bimonths prior to t) choice feeder steer prices in Kansas City. Both input prices were specified in 1967 dollars by dividing by the index of prices paid by farmers for production items, interest, taxes, and wages. All data were obtained from U.S. Department of Agriculture (USDA) sources.

Price Expectations Models

The models used to estimate the mean and variance of the price distributions will be discussed in this section.

[1] The five- to eight-month lag reflects the feeding periods for both the midwestern and western regions as indicated by Gee, Van Arsdall, and Gustafson.

[2] Hurt and Garcia find that uncertainty in input prices also significantly influences sow farrowings. Although uncertainty in corn price during the feeding period may affect supply response, we have chosen, as do most other authors, to focus on output price uncertainty. Soybean price was also included in the supply response to reflect an additional input cost. However, it was statistically insignificant and, hence, omitted from the supply response equations.

[3] A bimonthly model was chosen because it was most consistent with the futures market data. Contract delivery dates for live cattle occur every other month starting in February. Hence, each bimonth would reflect only one futures contract delivery date.

Naive Expectations

Expectations are naive if the producer simply uses the output price at the time inputs are purchased as the expected sale price. These expectations were estimated by deflating average monthly price received by U.S. farmers for beef cattle to 1967 dollars by the monthly consumer price index. (The bimonthly deflated fed cattle price calculated from this series is denoted by $PCAT_t$.) The mean and variance of the monthly prices three to four bimonths (or five to eight months) prior to bimonth t were used to estimate P_t^* and σ_t^*; they are denoted by PNM_t^* and PNV_t^*, respectively. For example, to estimate the naive expectations variables for the first bimonth of 1972, the mean and variance of monthly prices from May through September of 1971 were calculated. For the second bimonth of 1972, monthly observations from July through November of 1971 were used, etc.

ARIMA Forecasts

Another method using only past prices to estimate price expectations is the ARIMA model. The bimonthly deflated fed beef price series, $PCAT_t$, between 1961 and 1984 was identified to most closely follow either an ARIMA (2,1,0) or an ARIMA (1,1,1) process. Different forecasts of the mean and variance were obtained for each model. A moving ARIMA model using ten years of the $PCAT_t$ data series was used to find three- and four-bimonth-ahead forecasts and their respective mean-square forecasting errors for each of the time periods between 1972 and 1984. For example, the mean and variance for the first bimonth of 1972 were estimated as follows. A three-step-ahead forecast and the corresponding mean-square forecasting error were obtained for the ARIMA model using data between the fifth bimonth of 1961 and the fourth bimonth of 1971. A four-step-ahead forecast and the mean-square forecasting error were also obtained using bimonthly price data between the fourth bimonth of 1961 and the third bimonth of 1971. The average of the three- and four-step-ahead forecasts were used to approximate the mean, and the average of the mean-square forecasting errors formed the estimate of the variance. Estimates of the mean and variance for the second bimonth of 1972 were obtained from three-bimonth-ahead forecasts (using data from 1961–66 to 1971–75) and four-bimonth-ahead forecasts (using data from 1961–65 to 1971–74), and so forth.

Futures Prices

Producers also may use the price of the futures contract maturing when output will be marketed as their expectation of output price. The price expectations based on futures prices were estimated from data in the *Chicago Mercantile Exchange Yearbook*. For the live cattle futures contract maturing in each bimonth from 1972 through 1984, thirteen daily deflated futures prices were selected from the three to four bimonths prior to contract maturity.

More specifically, the mean and variance for the first bimonth of 1972 were calculated as follows. The February 1972 futures contract was used because it matured during the first bimonth of the year. Thirteen daily opening prices of this contract were selected from the previous three to four bimonths (i.e., May, June, July, and August of 1971). The daily prices selected from May 1971 were deflated to 1967 dollars by the monthly consumer price index for May 1971, those selected from June were deflated by the consumer price index for the month of June, etc. The mean and variance of these thirteen prices were computed. For the second bimonth of 1972, thirteen daily opening prices of the April 1972 contract were selected from March through June of 1971, etc. However, the price expectations computed from the futures data may not precisely correspond with the $PCAT_t$ data series because futures prices reflect a specific quality of cattle for particular delivery points while the $PCAT_t$ series is based on national average prices.

Adaptive Expectations

The adaptive expectations model (Nerlove) posits that producers revise their expectations in proportion to the error associated with the previous level of expectations:

$$(2) \quad P_t^* - P_{t-r}^* = \lambda(P_{t-r} - P_{t-r}^*) \quad 0 < \lambda \leq 1$$

$$(3) \quad \sigma_t^* - \sigma_{t-r}^* = \gamma(\sigma_{t-r} - \sigma_{t-r}^*) \quad 0 < \gamma \leq 1.$$

Equation (2) can be restated using the lag operator L as

$$(1 - (1 - \lambda)L^r)P_t^* = \lambda P_{t-r}$$

and solving for P_t^*:

$$(4) \quad P_t^* = \frac{\lambda}{1 - (1 - \lambda)L^r} P_{t-r}.$$

Similarly, an expression can be found for σ_t^*:

$$\sigma_t^* = \frac{\gamma}{1 - (1 - \gamma)L^r} \sigma_{t-r}. \tag{5}$$

Because producers purchase feeder cattle three to four bimonths prior to marketing, the naive expectations of mean and variance defined earlier, PNM_{t-r} and PNV_{t-r}, are used to estimate the moments of fed cattle price in previous periods, P_{t-r} and σ_{t-r}. The supply response function can be obtained by substituting equations (4) and (5) into (1) and multiplying through by the expressions containing lag operators in the denominators.

$$AQCAT_t = \beta_o^a + \sum_{i=1}^{5} \beta_i^a S_{it} + \beta_6 APCN_{t-r} + \beta_7 APF_{t-r} + \beta_8 AP_t^* + \beta_9 A\sigma_t^* + V_t, \tag{6}$$

where

$$AQCAT_t = QCAT_t - (2 - \lambda - \gamma)QCAT_{t-r} + (1 - \lambda)(1 - \gamma)QCAT_{t-2r}$$

$$APCN_{t-r} = PCN_{t-r} - (2 - \lambda - \gamma)PCN_{t-2r} + (1 - \lambda)(1 - \gamma)PCN_{t-3r}$$

$$APF_{t-r} = PF_{t-r} - (2 - \lambda - \gamma)PF_{t-2r} + (1 - \lambda)(1 - \gamma)PF_{t-3r}$$

$$AP_t^* = \lambda PNM_{t-r} - \lambda(1 - \gamma)PNM_{t-2r}$$

$$A\sigma_t^* = \gamma PNV_{t-r} - \gamma(1 - \lambda)PNV_{t-2r}$$

$$V_t = \epsilon_t - (2 - \lambda - \gamma)\epsilon_{t-r} + (1 - \lambda)(1 - \gamma)\epsilon_{t-2r}.$$

The adaptive means and variances, AP_t^* and $A\sigma_t^*$, are estimated separately by using results from the naive expectations model. Just (1977), however, points out that simultaneously estimating the means and variances within the supply response function would yield more efficient estimates of the coefficients.

Rational Expectations

The Muth rational expectations hypothesis maintains that producers act as if they were solving the market supply and demand system when forming their expectations. The supply equation will be identical to the one defined earlier

$$QCAT_t = a_o + \sum_{i=1}^{5} a_i S_{it} + bP_t^* + c\sigma_t^* + dPCN_{t-r} + ePF_{t-r} + \epsilon_t. \tag{7}$$

The farm-level demand equation is specified in price dependent form to reflect that quantity is predetermined in period t and is given by

$$PCAT_t = f + gQCAT_t + hI_t + iY_t + U_t, \tag{8}$$

where Y_t is per capita disposable income in bimonth t, I_t is a farm-level index of other meats in bimonth t and equals

$$\sum_j P_t^j Q_t^j \Big/ \left(\sum_j P_t^j Q_t^j + PCAT_t \cdot QCAT_t \right),$$

where P^j and Q^j are the farm-level prices and quantities of chicken and pork,[4] and U_t is error in bimonth t.

Per capita disposable income was obtained from USDA sources and deflated to 1967 dollars by the consumer price index. The farm-level index of other meats was calculated from the following USDA data: young chicken slaughter, commercial hog slaughter, and average prices received by farmers for broilers and hogs.

The rational expectation of the mean of fed cattle price was found by first substituting equation (7) into (8).

$$PCAT_t = f + g\left(a_o + \sum_{i=1}^{5} a_i S_{it} + bP_t^* + c\sigma_t^* + dPCN_{t-r} + ePF_{t-r} + \epsilon_t\right) + hI_t + iY_t + U_t. \tag{9}$$

Taking expectations of both sides of equation (9), assuming that expectations are rational [i.e., $E(PCAT_t) = P_t^*$], and solving for P_t^* we obtain

$$P_t^* = \frac{f + g\left(a_o + \sum_{i=1}^{5} a_i S_{it}\right) + gc\sigma_t^* + gdPCN_{t-r} + gePF_{t-r} + hI_t^* + iY_t^*}{1 - gb}, \tag{10}$$

[4] This is the same model as the one specified by Antonovitz and Roe. However, they did not estimate the system simultaneously because producers were not assumed to have rational expectations. A reviewer pointed out that a failure to account for structural changes in the demand for meats may lead to rejection of the rational expectations hypothesis for the wrong reason. However, Chalfant and Alston found that specification errors in econometric demand studies can account for findings of taste changes. Thus, the problem is essentially one of realizing that specification of the demand function influences the expressions of and subsequent tests of the rational expectations hypothesis.

where I_t^* and Y_t^* are the expectations of the income and index variables formulated by producers when inputs are purchased. To find the rational expectation of the variance of fed cattle price, the expression for P_t^* in equation (10) is substituted into (9):

$$(11)\quad PCAT_t = f + g\left(a_o + \sum_{i=1}^{5} a_i S_{it}\right) + gb\left[f + g\left(a_o + \sum_{i=1}^{5} a_i S_{it}\right) + gc\sigma_t^* + gdPCN_{t-r} + gePF_{t-r} + hI_t^* + iY_t^*\right]\Big/(1 - gb) + gc\sigma_t^* + gdPCN_{t-r} + gePF_{t-r} + g\epsilon_t + hI_t + iY_t + U_t.$$

If P_t^* is subtracted from the left-hand side of equation (11) and its equivalent from equation (10) is subtracted from the right-hand side of (11), the resulting expression is

$$(12)\quad P_t - P_t^* = h(I_t - I_t^*) + i(Y_t - Y_t^*) + g\epsilon_t + U_t.$$

Squaring both sides of equation (12), taking the expected value, and assuming that the exogenous variables are uncorrelated with the error terms, we obtain

$$(13)\quad E(PCAT_t - P_t^*)^2 = \sigma_t^* = h^2IV_t^* + i^2YV_t^* + 2hiCOV_t^* + g^2E(\epsilon_t^2) + E(U_t^2) + 2gE(U_t\epsilon_t),$$

where IV_t^* and YV_t^* are the expected variances of index and income for bimonth t, and COV_t^* is the expected covariance between income and index for bimonth t, with all expectations formulated when inputs are purchased.

If the expressions for the rational expectations mean and variance, equations (10) and (13), are substituted back into supply equation (7), the demand and supply system can be written as[5]

$$(14)\quad PCAT_t = f + gQCAT_t + hI_t + iY_t + U_t, \text{ and}$$

$$(15)\quad QCAT_t = \frac{a + bf}{1 - gb} + \frac{\sum_{i=1}^{5} a_i S_{it}}{1 - gb} + \frac{d}{1 - gb}PCN_{t-r} + \frac{e}{1 - gb}PF_{t-r} + \frac{ch^2}{1 - gb}IV_t^* + \frac{ci^2}{1 - gb}YV_t^* + \frac{bh}{1 - gb}I_t^* + \frac{bi}{1 - gb}Y_t^* + \frac{2hic}{1 - gb}COV_t^* + \frac{c}{1 - gb}E(U_t^2) + \frac{cg^2}{1 - gb}E(\epsilon_t^2) + \frac{2cg}{1 - gb}E(U_t\epsilon_t) + \epsilon_t.$$

Wallis suggests that the expected values of the exogenous variables, I_t^* and Y_t^*, can be estimated by ARIMA models. Hence, a procedure similar to that employed to obtain expectations of fed cattle price from ARIMA models was used. Using bimonthly data between 1961 and 1984, deflated per capita disposable income was identified to most closely follow an ARIMA (1,1,0) process; the index variable followed an ARIMA (1,2,1) process. Moving ARIMA models, estimated with ten years of data to find three- and four-bimonth-ahead forecasts and mean square forecasting errors, were again used to calculate I_t^*, Y_t^*, IV_t^*, and YV_t^*. The covariance variable was approximated by first determining a simple moving covariance between I_t and Y_t using previous ten years of data. The average of the covariances three and four bimonths prior to t formed the estimate of COV_t^*.

Empirical Results

Prior to presenting the empirical results, it is necessary to consider the effects of using generated or constructed variables (for anticipated prices and variances) in the estimations. If producers respond to realizations from stochastic processes that generate output prices and variances, then we are in a stochastic regressors world. This interpretation is plausible because producers have to make decisions based on actual forecasts of future unknown output prices and variances. This view is also consistent with the methods used to generate price and variance

[5] For estimation purposes, the terms involving $E(U_t^2)$, $E(\epsilon_t^2)$, and $E(U_t\epsilon_t)$ were omitted in equation (15). If these terms are constant over time, then their omission will only bias the intercept term. However, as pointed out by Aradyula and Holt, the rational expectation of the variance will be constant over time unless the variances of the exogenous variables vary over time. In our case [see equation (13)], this implies that IV_t^* and YV_t^* must vary over time.

forecasts since actual output prices (and variances) are not known until three or four bimonths in the future. In this situation, assuming that regressors are contemporaneously uncorrelated with the disturbance terms (which seems reasonable, given the nature of the generated forecasts) and conditional upon the realizations of prices and variances, maximum likelihood estimators are consistent and asymptotically efficient and the usual test statistics hold. (See, e.g., Judge et al.) On the other hand, the errors-in-variables assumption that producers react to the true unobserved mean (and variance) seems unreasonable, except perhaps in the true rational expectation case. This model together with potential estimation and statistical inference problems is discussed in detail, e.g., by Pagan. However, in this framework no complete treatment of the estimation and inference difficulties has been developed to account for predictions and squared prediction errors as regressors in the context of autocorrelation (our case). Furthermore, no instrumental variables appear readily available to improve upon a situation where five- to eight-month-ahead forecasts together with their mean-squared forecast errors are already used to generate the price and variance predictors. Thus, if the stochastic regressors story fits what cattle producers do, then the empirical results can be interpreted as conditional upon the price realizations with the maximum likelihood estimators possessing all the usual desirable sampling properties. The more complicated errors-in-variables model would be inappropriate.

Naive, ARIMA, and Futures Models

Supply response functions as given by equation (1) were estimated for the naive expectations, ARIMA forecasts, and futures price models. The data were scaled to improve the accuracy of the estimation. Each of the four supply equations had significant first-order autocorrelation; hence, modified Cochrane-Orcutt procedures were used to obtain maximum likelihood estimates. Results are presented in table 1.

The coefficient on corn price was negative for all models and significantly different from zero based on asymptotic t ratios except for the model based on futures prices. This result indicates that higher feed costs result in lower production. For

Table 1. Estimates of the Supply Response for Naive, ARIMA, Futures, and Rational Expectations Models

	Price Expectations Models				
Independent Variables	Naive	ARIMA (2,1,0)	ARIMA (1,1,1)	Futures	Rational
Constant	3.582**[a]	5.358**	4.224**	3.486**	1.374
	(11.207)[b]	(9.848)	(10.023)	(11.337)	(.833)
Seasonal 1	.222**	.237**	.243**	.229**	.212**
	(4.019)	(4.303)	(4.284)	(4.212)	(3.396)
Seasonal 2	.165*	.194**	.204**	.209**	−.106
	(2.328)	(2.980)	(2.964)	(3.154)	(−.557)
Seasonal 3	.069	.109	.112	.138	−.128
	(.8910)	(1.502)	(1.422)	(1.874)	(−.887)
Seasonal 4	.045	.046	.058	.100	−.124
	(.6434)	(.694)	(.849)	(1.362)	(−1.106)
Seasonal 5	.208**	.170**	.184**	.216**	−.021
	(3.698)	(2.966)	(3.278)	(3.796)	(−.158)
Corn price	−.412*	−.800**	−.677**	−.323	.005
	(−2.430)	(−3.134)	(−3.284)	(−1.289)	(.014)
Feeder cattle price	.269	−.242	−.137	.161	−.297
	(1.327)	(−.8388)	(−.555)	(.995)	(−1.914)
Expectation of fed cattle price	−.040	.019	.006	−.026	.936
	(−1.307)	(.555)	(.244)	(−1.039)	(1.743)
Variance of fed cattle price	−.006	−.039*	−.032*	.005	1569.5
	(.590)	(−2.383)	(−2.242)	(.479)	(.617)
Autocorrelation coefficient	.591**	.47**	.501**	.617**	.413**
	(6.303)	(4.601)	(4.985)	(6.752)	(3.903)
R^2	.642	.671	.664	.640	.676

[a] Single asterisk indicates significance of a two-tailed test at the .05 level; double asterisk indicates significance of a two-tailed test at the .01 level.
[b] Values in parentheses are t-ratios.

feeder cattle price, the coefficient was not significant in any of the models, although it was positive for the naive and futures price expectations and negative for the ARIMA's. As Freebairn and Rausser point out, the insignificance of these results is not surprising given the high degree of correlation between fed cattle and feeder cattle prices. The simple correlation coefficients between expected fed cattle and feeder cattle prices are 0.94, 0.92, 0.93, and 0.81, respectively, for the naive, ARIMA (2,1,0) ARIMA (1,1,1) and futures equations.

A negative supply response to the expectation of fed cattle price occurred for both ARIMA models, and a positive response occurred for the naive and futures price expectations. However, none of the coefficients were significantly different from zero. Jarvis showed theoretically that short-run supply response to an increase in the price of cattle should be negative, although short-run steer and bull supply were positively sloped in his empirical analysis. In subsequent work, Paarsch showed that slight changes in the underlying assumptions of the theoretical model may lead to a positive supply response. Empirical results for short-run fed beef supply functions have been mixed; evidence has supported both negative and positive response, although the coefficients have often been statistically insignificant (Nelson and Spreen). Interestingly, in the research presented here the evidence to support either model is not overwhelming because the use of different expectations models in the supply response function may lead to opposite signs on the coefficient of expected fed cattle price.

If producers are risk averse, they should reduce production when expected variation in output price increases. The negative and significant coefficient on the variance of fed cattle price in both ARIMA models supports this hypothesis. The naive model also has a negative, although insignificant, coefficient, while the result for the model based on futures prices is positive and insignificant.

Based on the number of statistically insignificant coefficients of expected prices and variances, one might infer that expectations and risk are unimportant in fed beef supply response equations. However, this is not necessarily the case. Statistically significant partial F values were obtained at the 5% level for four of the six response models when testing that the coefficients on expected price and variance are simultaneously equal to zero. The partial F-statistic values for the naive, futures, ARIMA (2,1,0), ARIMA (1,1,1) and rational expectations models are, respectively, 0.89, 0.65, 5.26, 3.97, and 7.20. The critical $F(2,64)$ value, at the 5% level, is 3.14. The partial F-test for the adaptive model was not performed since the mean was already highly significant. Hence, only the naive and futures models yielded insignificant partial F values, and the shortcomings of these two models have already been discussed. Many of the insignificant coefficients were due, in part, to high multicollinearity among the explanatory variables; more will be said about these problems below.

The elasticity estimates of both the mean and variance of fed cattle price, together with their associated standard errors, are reported in table 2. Not only are the signs different, but the magnitudes of the elasticities may vary significantly as well. For example, the elasticities of expected price are quite different for the two ARIMA models: .150 and .051. However, the elasticities of the variance are quite similiar: −.144 and −.136. For the naive model, in which producers are using the least amount of information, the elasticity of supply response to expected price is a relatively large value of −.311. If expectations are based on future prices, own-price elasticity has a value of −.227.

Table 2 indicates that the standard errors are rather large for the expected means and vari-

Table 2. Elasticities of the Expectation and Variance of Fed Cattle Price

	Naive	ARIMA (2,1,0)	ARIMA (1,1,1)	Futures	Adaptive	Rational
Expectation	−.311	.150	.051	−.227	−.838	.707
	(.238)[a]	(.271)	(.227)	(.219)	(.071)	(.406)
Variance	.004	−.144	−.136	.003	.001	.102
	(.075)	(.061)	(.061)	(.438)	(.006)	(.167)

[a] Standard errors are reported in parentheses. They were calculated at the mean values of the respective variables, assuming as is often done that the expected price and quantity of fed beef ratios are exogenous. An alternative procedure would be to obtain standard errors by the bootstrap procedure.

ances in the various models. In order to determine if these large standard errors were resultant from, in part, multicollinearity problems, the simple correlation coefficients between the explanatory variables were obtained, auxiliary regressions were run by regressing each explanatory variable on all the remaining explanatory variables, and condition numbers were found (e.g., Judge et al.). The primary problem apparently is the high correlation between feeder price and expected fed price (simple correlation coefficients of over 0.9 in four of the six models). In addition the auxiliary regressions indicated a strong linear relationship among feeder price and the remaining explanatory variables and among expected fed price and the other independent variables [adjusted R^2 values of approximately 0.98 were found, for example, in the ARIMA (1,1,1), ARIMA (2,1,0) and rational expectation models]. Finally, condition numbers of over 200 were obtained for the time series and futures models. These measures indicate the source of some of the difficulties in estimating supply response with expected prices and risk terms explicitly incorporated into the models.

Table 3. Estimate of Supply Response for Adaptive Expectations

Independent Variables	Coefficients
Constant	2.504**[b]
	(16.96)[c]
Seasonal 1	.255**
	(4.910)
Seasonal 2	.211**
	(3.517)
Seasonal 3	.087
	(1.548)
Seasonal 4	.099
	(1.799)
Seasonal 5	.218**
	(4.486)
Corn Price[a]	−.105
	(−.892)
Feeder cattle price[a]	.676**
	(27.85)
Adaptive expectation of fed cattle price[a]	−1.096**
	(−11.77)
Adaptive variance of fed cattle price[a]	.002
	(.269)
Autocorrelation coefficient	.363**
	(3.454)

[a] The dependent and all independent variables are weighted sums of lagged variables where $\lambda = .66$ and $\gamma = 1.00$. (See equation (6) for specific expressions.)
[b] Double asterisk indicates significance of a two-tailed test at the .01 level.
[c] Values in parentheses are t-ratios.

Adaptive Expectations

Equation (6) must be estimated to determine a supply response with adaptive expectations. However, if the ϵ_t's are independently and identically distributed, then the V_t's follow a higher-order moving-average process. Hence, a combination of generalized least squares and a two-dimensional grid search over λ and γ was attempted, but computer computations were unsuccessful probably because of the complexity of the specification of the variance matrix for the V_t's. Alternatively, equation (6) was estimated using a maximum likelihood procedure with a correction for autocorrelation, and a grid search was performed over λ and γ.

Results are presented in table 3. The minimum error sum of squares was obtained when $\lambda = .66$ and $\gamma = 1.00$. This result gives an interesting interpretation to equations (2) and (3): Although producers may use a naive expectation of the variance of fed cattle price, they revise their expectation of the mean in an adaptive manner. A negative and highly significant supply response to expected price is observed. The coefficient on the variance of price is positive, but insignificant. Elasticities for the adaptive model (reported in table 2) are quite different from the previously discussed models. The largest negative elasticity, −.838, is observed for expected price; while for the variance, the elasticity is .001, which is closer to zero than any other model. For the coefficient on corn price, a negative but insignificant sign is observed. The coefficient on cattle price is positive and significant.

Rational Expectations

The supply and demand system implied by rational expectations is given by equations (14) and (15). Because there are twelve variables in the equations but only nine underlying coefficients to be estimated (a through i), there are three restrictions. This system, with its restrictions, can be written succinctly as

$$(16) \quad PCAT_t = \alpha_1 + \alpha_2 QCAT_t + \alpha_3 I_t + \alpha_4 Y_t + \eta_t,$$

$$(17) \quad QCAT_t = \beta_o^r + \sum_{i=1}^{5} \beta_i^r S_i + \beta_6^r PCN_{t-r} + \beta_7^r PF_{t-r} + \beta_8^r I_t^* + \beta_9^r Y_t^* + \beta_{10}^* IV_t^* + \beta_{11}^r YV_t^* + \beta_{12}^r COV_t^* + \epsilon_t,$$

Table 4. Reduced-Form Estimates of the Restricted Supply Response and Demand Equations for Rational Expectations

Supply		Demand	
Independent Variables	Coefficients	Independent Variables	Coefficients
Constant	3.509**[a] (8.039)[b]	Constant	−3.600 (−1.510)
Seasonal 1	.139** (2.977)	Quantity of fed cattle	2.265** (4.279)
Seasonal 2	.147** (3.482)	Index of other meats	.003 (.813)
Seasonal 3	.104** (2.815)	Per capita disposable income	−.033 (−.792)
Seasonal 4	.078* (2.208)		
Seasonal 5	.096* (2.478)		
Corn price	−.355** (−3.202)		
Feeder cattle price	.109** (3.832)		
Mean of index of other meats	−.014 (NA)[c]		
Mean of per capita disposable income	−.005 (−.261)		
Variance of index	−.020 (NA)[c]		
Variance of income	−1.936* (−2.511)		
Covariance of income and index	.397 (NA)[c]		

Note: The value of the log-likelihood function is 12.26.
[a] Single asterisk indicates significance of a two-tailed test at the .05 level; double asterisk indicates significance of a two-tailed test at the .01 level.
[b] Values in parentheses are t-ratios.
[c] Values of the t-statistics were not available because these coefficients were not directly estimated due to the imposition of cross-equation restrictions.

where

$$\beta_8^r = \beta_9^r\alpha_3/\alpha_4;\ \beta_{10}^r = \alpha_3^2\beta_{11}^r/\alpha_4^2;\ \beta_{12}^r = 2\beta_{11}^r\alpha_3/\alpha_4.$$

Full information maximum likelihood estimates were obtained for equations (16) and (17) with and without the restrictions. Tests of the restrictions are often used to test the validity of the Muth rational expectations hypothesis. The likelihood ratio test rejected the hypothesis that the three restrictions jointly held ($\chi^2 = 11.34$ with three degrees of freedom). Thus, the data do not support the hypothesis that producers form expectations of the mean and variance of fed cattle price rationally.

The reduced-form estimates of the restricted supply and demand system are presented in table 4. In the supply equation, the coefficient on corn price is negative and significant as expected. However, as with adaptive expectations, the coefficient on feeder cattle price was significantly positive. The negative significant coefficient on the variance of income is an intuitively appealing result. Because beef is a normal good, we would expect that uncertainty about per capita disposable income may result in a lower quantity marketed. In the demand equation, the only statistically significant coefficient was for quantity of fed cattle. Unfortunately, its sign was positive, which is counterintuitive.

The rational expectations of the mean and the variance of fed cattle price were predicted from equations (10) and (13).[6] Similar to the naive, futures, and ARIMA models, the single equation supply response given by (1) was estimated with the predictions of the rational expectation of the mean and variance. This was done for two reasons: to have a direct comparison with

[6] Because $E(U_t^2)$, $E(\epsilon_t^2)$, and $E(U_t/\epsilon_t)$ are assumed constant over time, they were omitted from the estimation of the rational expectations variance in equation (13). Clearly, the estimate of the coefficient on the variance will be unaffected by this omission and only the estimation of the intercept will be affected.

the other estimates of supply response and to test the validity of the rational expectations model in a nonnested test. (This will be discussed in the next section.) The results are presented in the last column of table 1. All of the coefficients on input prices and expectations were insignificant. Corn price had a positive coefficient while feeder cattle price had a negative one. Positive supply responses to both the rational expectation of the mean and variance were observed. The largest positive elasticity of supply response with respect to the expected fed cattle price, .707, was observed for the rational expectations model as indicated in table 2.

Shonkwiler and Hinckley estimate that the bimonthly elasticity of placements of cattle in feedlots with respect to expected fed cattle price was 1.221. They suggest that these placements represent 600-pound feeder steers and heifers that will be fed for three bimonths. We would anticipate that the response of placements to expected price would be greater than that of fed cattle marketings because there is no problem of heterogenous production lags with the specification in terms of placements. Of course, placements three bimonths prior to marketing represent only a fraction of total fed cattle marketed. As expected, all of the elasticities estimated in this study are, in absolute value, smaller than Shonkwiler and Hinckley's estimates.

Nonnested Hypothesis Tests

Given the supply response functions estimated using each of the six models of price expectations, it would be useful to know which model gives the best specification and, hence, which price expectation model most precisely reflects actual expectations. Unfortunately, because the supply response functions are not nested (i.e., no one model is a more general specification of any other model), it is not possible to use common tests based on the F-statistic or likelihood ratio. It is possible, however, to test among these non-nested models by using the J-test suggested by Davidson and MacKinnon.[7]

Davidson and MacKinnon consider the case of the single equation, possibly nonlinear regression model, the truth of which we wish to test:

$$(18)\qquad H_0: y_t = f(X_t, \beta) + \epsilon_{ot},$$

where y is the dependent variable, X is a matrix of independent variables, β is a vector of parameters to be estimated, and the error term ϵ_{ot} is assumed to be $NID(0, \sigma_o^2)$. Suppose economic theory suggests an alternative hypothesis:

$$(19)\qquad H_1: y_t = g(Z_t, \psi) + \epsilon_{1t},$$

where Z is a matrix of exogenous variables, ψ is a vector of parameters to be estimated, and ϵ_{1t} is $NID(0, \sigma_1^2)$ if H_1 is true. Consider the possibly nonlinear regression

$$(20)\qquad y_t = (1 - \Phi)f(X_t, \beta) + \Phi\hat{g}_t + \epsilon_t,$$

where $\hat{g}_t = g(Z_t, \hat{\psi})$ and $\hat{\psi}$ is the maximum likelihood estimate of ψ. If H_o is true, then the true value of Φ is zero. By using a conventional asymptotic t-test, the validity of whether $\Phi = 0$ can be tested; this is called the J-test.

Because significant first-order autocorrelation was detected in all the models except rational expectations, it was necessary to modify the J-test. Under H_o (i.e., $\Phi = 0$), with a first-order autoregressive scheme, equation (20) becomes

$$(21)\qquad y_t = f(x_t, \beta) + \epsilon_{ot},$$

where $\epsilon_{ot} = \rho_o\epsilon_{o,t-1} + \nu_t$ and ν_t is a white noise process. Thus, in the J-test we need to correct for first-order autocorrelation using ρ_o, i.e., equation (20) is modified to

$$(22)\qquad y_t = \rho_o y_{t-1} + (1 - \Phi)f((X_t - \rho_o X_{t-1}), \beta) + \Phi\hat{g}_t + \epsilon_t,$$

where $\hat{g}_t = g(Z_t, \hat{\psi})$ and $\hat{\psi}$ is the maximum likelihood estimate of ψ obtained from the following first-order autocorrelation transformed equation

$$(23)\qquad y_t = \rho_1 y_{t-1} + g((Z_t - \rho_1 Z_{t-1}), \psi) + \epsilon_{1t}.$$

We corrected for autocorrelation in the estimation of ψ, but we did not use the AR structure to calculate the predicted values, $\hat{g}(Z_t, \hat{\psi})$. The idea is to get efficiency in the estimation of ψ, but not include the AR structure in an extended model used for calculating $\hat{g}_t$. The latter point is most important because if we were to use $(\hat{g}_t + \hat{\rho}_1\hat{e}_{1,t-1})$, i.e., predictions corrected for autocorrelation, as the "variable" for which Φ is estimated, we run the risk of a significant estimate of Φ only because of the AR disturbance structure.

The modified J-test given in equation (22) was used to test the null hypothesis that each of the models based on naive expectations, ARIMA

[7] Orazem and Miranowski also use nonnested testing procedures to compare different expectations hypotheses. However, their work involves acreage allocations in Iowa, does not include the variance or higher moments, and considers only one of the expectation regimes examined in this paper.

forecasts, and futures prices were true against each of the remaining models. However, in the adaptive model, $QCAT_t$ was not the dependent variable, yet the specification of equation (22) requires a predicted value of $QCAT_t$ for $\hat{g}_t$. Hence, $\hat{g}_t$ was obtained from the estimate of equation (6) as

$$\hat{g}_t = AQ\hat{C}AT_t - .33QCAT_{t-r}$$

since $\lambda = .66$ and $\gamma = 1.00$. For the rational expectations model, the predicted value of $QCAT_t$ was obtained from the estimate of equation (15).

To test the supply response function with adaptive expectations against each of the other models, the modified *J*-test was again used. However, as noted previously, the dependent variable in the adaptive model was $AQCAT_t$ rather than $QCAT_t$. Hence, $\hat{g}_t$ is the predicted value of $AQCAT_t$ and was estimated as

$$\hat{g}_t = QC\hat{A}T_t - .33\ QCAT_{t-r}.$$

It is not possible to use the *J*-test to test a model with a multiequation specification against a single equation model. Thus, to test the validity of the model based on rational expectations against each of the other models, the single equation supply response estimated with the rational expectations predictors of the mean and variance discussed previously was used.

In table 5, the results of the pairwise *J*-tests are presented. The truth of each of the models based on ARIMA forecasts, futures prices, and naive and adaptive expectations is rejected by each of the other models except adaptive expectations. The hypothesis that adaptive expectations is the true model is rejected by each of the other models except rational expectations. Hence, the *J*-tests do not support any one model in particular with perhaps the least evidence for the adaptive model. To provide information in addition to the *J*-tests, the within-sample root-mean-square errors were also calculated for each of the models. These values were .152, .154, .159, .159, .142, and .209 for the naive, ARIMA (2,1,0), ARIMA (1,1,1), futures, adaptive, and rational expectations models, respectively. The highest value was observed for the rational expectations model perhaps adding additional evidence to reject the hypothesis that expectations are formed rationally. Somewhat contrary to the results of the *J*-tests, the supply response based on adaptive expectations has the lowest root-mean-square error.

Conclusions

The empirical analysis leads us to conclude that no one expectations model dominates the rest. Thus, the evidence suggests that expectations are heterogenous rather than homogenous. Furthermore, a meticulous examination of the empirical results indicates that multicollinearity problems, especially between feeder prices and expected fed prices, may lead to many insignificant individual coefficients, causing the analyst to conclude that expectations play a minor role in fed beef response decisions. While we cannot completely rule out this interpretation, the partial *F* tests strongly indicate that taken together expected price and risk factors significantly influence fed beef supply decisions. These findings may be of considerable value for researchers who attempt to analyze supply response models.

As previously mentioned, researchers have suggested that expectations based on futures prices and ARIMA models may be quite similar to Muth's concept of rational expectations. This work gives clear evidence to refute this hypothesis. Not only does the sign of the supply response differ for these models, but elasticities are quite different as well.

Table 5. Pairwise Tests for Hypotheses

	Alternative Hypothesis	H_{A210}	H_{A111}	H_{NAIVE}	$H_{FUTURES}$	$H_{ADAPTIVE}$	H_{RE}
Tested Hypothesis:	H_{A210}		4.37**[a]	4.38**	4.28**	1.80	3.77**
	H_{A111}	4.71**		5.03**	4.83**	1.63	4.21**
	H_{NAIVE}	6.55**	5.63**		6.40**	.03	2.38*
	$H_{FUTURES}$	7.18**	7.04**	6.33**		−.26	2.42*
	$H_{ADAPTIVE}$	4.12**	4.22**	4.58**	4.96**		1.58
	H_{RE}	3.66**	3.66**	3.49**	5.10**	.98	

Note: Entries are ordinary *t*-statistics for ϕ in equation (22).
[a] Single asterisk indicates significance of a two-tailed test at the .05 level; double asterisk indicates significance of a two-tailed test at the .01 level.

This work provides strong evidence that researchers must be careful in their choice of expectations models when estimating supply response because signs and elasticities may be significantly different depending on which model is used. The results presented here also suggest that additional work is needed in both the theoretical and empirical aspects of the fed beef market. In particular, a rigorous theoretical model of heterogenous expectations needs to be developed and empirically tested. Additional empirical work correcting multicollinearity problems in supply response would be helpful. Further theoretical work in nonnested hypothesis testing would benefit researchers by enabling them to compare single and multiequation supply response models.

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Comments and Replies

Profit, Supply, and Factor Demand Functions: Comment

John R. Conlon

In Lau and Yotopoulos (1972) a new method of estimating production relations was developed, building on Lau and Yotopoulos (1971). This method, bringing together estimates of profit and factor demand functions, was further developed in Yotopoulos and Lau to incorporate a test of rationality. Their method has since been applied by Yotopoulos, Lau, and Lin; Sidhu; Sidhu and Baanante (1979, 1981); Jamison and Lau; and Junankar (1980a, b, 1982). Because the assumption of rationality is so fundamental to economics, and because few tests of this hypothesis exist, the Lau-Yotopoulos method is very important. However, these studies rest on advanced economic theory and sophisticated econometrics, so it is easy to be intimidated by them. Sophisticated estimators, however, are not necessarily free from error.

In this comment, it will be shown that many of the results obtained in the empirical profit function literature—both those which seem to support farmer rationality and those which seem to contradict it—can be explained, regardless of farmer behavior, if the wage is measured with an error.

The dual-approach estimators under discussion regress profit accruing to fixed factors against quantities of these fixed factors and prices of variable factors. Thus, suppose that there is only one fixed factor, Z, and one variable factor, X (labor, say), and let Y be output. Suppose, further, that the observed real wage to X (deflated by the output price) is W^* and let observed normalized profit $= \pi^* = Y - W^*X$. Then the profit function regression will be

$$(1) \qquad \ln \pi^* = C_0 - \beta \ln W^* + \delta \ln Z + e_1.$$

This regression is usually estimated with a factor share regression,

$$(2) \qquad W^*X/\pi^* = \mu + e_2.$$

If wages are measured accurately and profit maximization holds, then β should equal μ. This seems to give us a test of economic efficiency.

It is shown in this note, however, that even if farmers are not maximizing profits, measurement errors in W^* will tend to shift ordinary least squares (OLS) estimates of β towards μ. Thus, OLS profit function estimates which seem to confirm rationality may actually be caused by spurious correlation due to inaccurate wage data rather than reflecting rational farmer behavior.[1] A similar result would hold for analogous cost function estimates.

Note that this differs from the usual effect of measurement errors on OLS estimates. In most cases, measurement errors simply bias the coefficient of the mismeasured variable towards zero. In the case of OLS profit function estimates, however, measurement errors can be much more deceptive because they tend to give the economist spuriously encouraging results.

The actual tests of profit maximization do not use OLS profit function regressions. Instead they use joint estimates of the profit function equation (1) with the factor share equation (2) using Zellner's seemingly unrelated regressions (SUR) estimator. This note therefore next shows that, even if farmers are maximizing profits (so β should equal μ), joint estimators in the presence of measurement errors yield estimates of β which are biased down from μ. Thus, the usual tests of profit maximization based on joint estimates are biased toward rejection (though the standard errors of the estimates are usually so large that profit maximization is rarely rejected in practice). It also follows that joint estimates of (1) and (2) with the restriction $\beta = \mu$ imposed should be biased.

Quiggin and Bui-Lan have emphasized the potential significance of measurement errors in profit function estimation. They point out that if true wages are relatively constant in a cross section because of, say, labor mobility, then measurement errors may constitute a large fraction of the variation in observed wage.[2] They also note that wage coefficients in profit function regressions are generally less strongly negative when SUR rather than OLS is used, and they conjecture that this may be related to measurement errors. Their discussion, however, is apparently meant only to be suggestive, and their wording is ambigu-

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[1] This includes as a special case the result of Fuss, McFadden, and Mundlak that when firms maximize profits, errors in measuring the wage do not bias OLS estimates of (1).

[2] Junankar (1987) and Deaton (1988) also argue that observed price variation may in part be due to measurement errors.

ous if not contradictory or misleading.[3] In this note, we therefore replace their brief discussion with a consistent model. In so doing we confirm what in Quiggin and Bui-Lan's paper was only an undeveloped suspicion, that measurement errors provide a consistent explanation of the peculiarities of previous results in this important field.

Measurement Errors in OLS and Joint Estimates of the Profit Function

In this section it is shown that measurement errors cause OLS estimates of the profit function to mimic results which would follow from profit maximization, even when farmers are not maximizing profits. It is then shown that, if wages are measured with an error, then the usual test of rationality, based on SUR estimates of the profit function jointly with the factor share equation, will tend to reject profit maximization, even if farmers are maximizing profits.

Let output, Y, be a Cobb-Douglas function of input quantity X, giving

$$(3) \qquad Y = AX^{\alpha}e^{u+v}.$$

Here the fixed factor of production Z has been excluded for simplicity. In addition, productivity shocks u and v have been included, where u is anticipated by the farmer before input decisions are made, v is not anticipated by the farmer, and u and v are assumed independent with zero mean. The form of the error is similar to that given by Mundlak and Hoch.

Let W be the wage to labor deflated by the output price. Then setting expected marginal product equal to the wage times a systematic farmer error k gives

$$(4) \qquad \alpha AX^{\alpha-1}e^{u} = \alpha(Y/X)e^{-v} = kW,$$

using v unanticipated and, so, independent of X and u, and using the approximation $Ee^{v} = 1$. The specification of irrationality through the multiplicative factor k follows Lau and Yotopoulos (1971) and the general literature; $k = 1$ implies that profits are maximized. Rearranging (4) gives

$$(5) \qquad WX = (\alpha/k)Ye^{-v}.$$

Now assume that the observed real wage differs from the true real wage: $W^* = We^{\epsilon}$, where ϵ is a proportional error in observation, and where W, u, v, and ϵ are all uncorrelated with one another. Assume also that X and Y are observed without error (errors in Y could be subsumed under v; a model in which the measurement error affects both X and W is considered in the next section). Observed normalized profit is then

$$(6) \qquad \pi^* = Y - W^*X = Y - WXe^{\epsilon}.$$

Using equation (5) now yields

$$(7) \qquad \pi^* = (1 - [\alpha/k]e^{\epsilon-v})Y;$$

so, taking logs, and using a first-order Taylor approximation around $\epsilon - v = 0$, gives

$$(8) \qquad \ln \pi^* = \ln (1 - [\alpha/k]) + \ln Y + (\alpha/[k - \alpha])(v - \epsilon).$$

Solving (4) for X, plugging into (3) and solving for Y yields

$$(9) \qquad Y = \alpha^{\alpha/1-\alpha}A^{1/1-\alpha}k^{-\alpha/1-\alpha}W^{-\alpha/1-\alpha}e^{(1/1-\alpha)u+v}.$$

Taking logs and plugging into (8) gives

$$(10) \qquad \ln \pi^* = \ln (1 - [\alpha/k]) + (\alpha/1 - \alpha) \ln \alpha + (1/1 - \alpha) \ln A - (\alpha/1 - \alpha) \ln k - (\alpha/1 - \alpha) \ln W - (\alpha/[k - \alpha])\epsilon + (1/1 - \alpha)u + (k/[k - \alpha])v,$$

which, combining the constant terms, becomes

$$(11) \qquad \ln \pi^* = C - (\alpha/1 - \alpha) \ln W - (\alpha/[k - \alpha])\epsilon + (1/1 - \alpha)u + (k/[k - \alpha])v.$$

In addition, combining (7) with $W^* = We^{\epsilon}$ and (5), and using a linear approximation gives, for the factor share,

$$(12) \qquad W^*X/\pi^* = (\alpha/[k - \alpha]) + (k\alpha/[k - \alpha]^2)(\epsilon - v).$$

It can be seen from equation (11) that variation in ϵ will cause log observed profit, $\ln \pi^*$, to be negatively correlated with log observed wage, $\ln W^* = \ln W + \epsilon$, even if the log true wage, $\ln W$, is constant. Thus, when $\ln \pi^*$ is regressed against $\ln W^*$, spurious correlation will occur, even if there is no variation in the true wage. Furthermore, this spurious correlation mimics the profit maximization case. To see this, note from equation (11) that the coefficient on $\ln W^*$ in (1) is, in large samples,

$$(13) \qquad \begin{aligned} \text{plim}\, \hat{\beta} &= \text{Cov}(\ln \pi^*, \ln W^*)/\text{Var}(\ln W^*) \\ &= -\Theta(\alpha/1 - \alpha) - (1 - \Theta)(\alpha/[k - \alpha]) \\ &= -(\alpha/[k - \alpha]) - \Theta[(k - 1)\alpha/(1 - \alpha)(k - \alpha)], \end{aligned}$$

where

$$(14) \qquad \Theta = \sigma_w^2/(\sigma_w^2 + \sigma_\epsilon^2).$$

If measurement errors form a large part of the variation in the observed wage, that is, if σ_ϵ^2 is large compared to σ_w^2, then Θ will be small, and the estimate of β in equation (1), as seen in equation (13), will approach $\alpha/[k - \alpha]$, which is the OLS estimate of μ in equation (2), as seen in equation (12). Thus, if (1) and (2) are estimated separately using OLS, the results tend to mimic the case in which profits are

[3] For example, in the passage intended to explain why estimates of the factor price coefficient are larger when OLS is used than when SUR is used, they apparently assume that these OLS estimates are themselves close to zero. They also seem to think that the SUR estimator will somehow take the problem of measurement errors "into account." See also footnote 7.

maximized. A similar result could be proven for analogous cost function estimates.

Most profit function studies, however, test profit maximization by using joint SUR estimates of the profit function (1) with the factor share equation (2). If β in (1) is significantly different from μ in (2), then the hypothesis of profit maximization is rejected. However, joint estimates using Zellner's SUR method will be inconsistent in the presence of measurement errors, as is now shown.

Assume for simplicity that firms actually maximize profits, so $k = 1$. Then, using $\ln W + \epsilon = \ln W^*$, (11) becomes

$$(11') \quad \ln \pi^* = C - (\alpha/1 - \alpha) \ln W^* + (1/1 - \alpha)u + (1/1 - \alpha)v.$$

In addition, (12) becomes[4]

$$(12') \quad W^*X/\pi^* = (\alpha/1 - \alpha) + (\alpha/[1 - \alpha]^2)(\epsilon - v).$$

It can then already be seen that SUR will be biased, because the error term in (12′) is correlated with the independent variable $\ln W^* = \ln W + \epsilon$ in (11′).

The SUR estimator, essentially, takes linear combinations of regression equations, so that the resulting error terms are uncorrelated with each other, and then regresses the resulting equations using OLS (with weights, but that does not matter here). Regressing the error term in equation (11′) against the error term in equation (12′) gives regression coefficient

$$(15) \quad \phi = -(1 - \alpha)\sigma_v^2/\alpha(\sigma_v^2 + \sigma_\epsilon^2).$$

Note that this coefficient is zero unless $\sigma_v^2 \neq 0$. Thus, the SUR estimate will differ from OLS in this model only in the presence of farmer-unanticipated productivity shocks. Also note that equation (15) suggests that ϕ should be negative, between zero and $(1 - \alpha)/\alpha$ in absolute value. Unfortunately, none of the studies reviewed here report ϕ.

Using the regression coefficient ϕ, Zellner's SUR estimator, applied to (11′) and (12′), is equivalent to estimation of the equation

$$(16) \quad \ln \pi^* - \phi W^*X/\pi^* = C' - (\alpha/1 - \alpha) \ln W^* + (1/1 - \alpha)(u + v) - (\alpha/[1 - \alpha]^2)\phi(\epsilon - v)$$

and equation (12′) separately using OLS, where the errors in (16) and (12′) are now uncorrelated with each other.[5]

Unfortunately, the error in (16) now contains ϵ, and so is correlated with the regressor $\ln W^* = \ln W + \epsilon$. In fact, regressing the right-hand side of (16) against $\ln W^* = \ln W + \epsilon$, and using (15) gives, for the joint estimator of β the value,[6]

$$(17) \quad \text{plim}\beta_{joint} = (\alpha/1 - \alpha) \cdot \left\{1 - \frac{1}{\alpha} \frac{\sigma_v^2/\sigma_\epsilon^2}{([\sigma_v^2/\sigma_\epsilon^2] + 1)([\sigma_w^2/\sigma_\epsilon^2] + 1)}\right\}.$$

Note that this is an "unrestricted" estimate because β_{joint} is not restricted to equal the factor share estimate from (12′). Since this estimate is biased, the estimate with the restriction $\beta = \mu$ should also be biased.

Thus, the SUR estimate of β in the profit function regression will be biased downward away from $\alpha/(1 - \alpha)$. Furthermore, β_{joint} can even be of the wrong sign. This contrasts with the usual case, in which measurement errors bias the coefficient towards zero but do not cause the coefficient to have the wrong sign. Finally, note that the estimate is biased only if σ_v^2, the variance of the farmer-unanticipated productivity shock, differs from zero. Otherwise the error terms in the profit function regression and the factor share regression are uncorrelated [see discussion below equation (15)].

The above is consistent with the pattern in the empirical literature observed by Quiggin and Bui-Lan, that estimates of the coefficient of log wage have generally been lower in absolute value when SUR rather than OLS has been used, or even of the wrong sign.

Other Specifications of Measurement Errors

The last section examined the effects of a certain type of measurement error in detail. That measurement error, which we will continue to call ϵ, affected the observed wage, W^*, and through W^* the expenditure on the variable factor, W^*X, while the quantity of the variable factor, X, was known without error. Suppose, however, that the economist measures expenditure on the variable factor accurately but has inaccurate data on the quantity of the variable factor, say $X^* = Xe^{\epsilon'}$, where ϵ' is a new type of measurement error. Suppose further that an estimate of the wage is obtained by dividing the accurately measured expenditure by the inaccurately measured factor quantity, X^*. Then this estimated wage will be mismeasured as

$$(18) \quad W^* = Expenditure/X^* = WX/(Xe^{\epsilon'}) = We^{-\epsilon'}$$

where $Expenditure = WX = W^*X^*$ is measured without an error.

Because expenditure on the variable factor is measured without error, the profit and factor share in profit are both measured without error. With only $\ln W$ in

[4] A consistent estimate of α together with the variances and covariances of the error terms in (11′) and (12′) should yield estimates of the error structure. Work in progress is considering this issue. Unfortunately, none of the studies reviewed report the covariances between the error terms.

[5] The fact that SUR does not affect the estimation of (12′) is a special case of a result in Revankar (1974).

[6] This formula can, maintaining certain assumptions, be generalized to the n-input case.

equation (1) affected by the measurement error ϵ', the spurious correlation discussed in the last section does not occur. Thus OLS estimates suffer only from the downward bias that usually occurs in the presence of errors in the measurement of the independent variable. Furthermore, since the measurement error ϵ' does not affect the factor share, and so, the e_2 error in equation (2), that error will be independent of the observed wage in equation (1), so joint estimation will not lead to any additional biases in this case.

Suppose, however, that both types of measurement error occur, so

$$(19) \quad W^* = We^{\epsilon-\epsilon'}, X^* = Xe^{\epsilon'}, \text{ and } W^*X^* = WXe^{\epsilon},$$

This would be the effect, for example, of independent errors in measuring expenditure and X^*, with the wage obtained as expenditure divided by X^*. In this case, results similar to those in the last section will occur. The only differences will be that OLS estimates of β in (1) will be biased toward zero somewhat, and that now there will be two reasons why e_1 from equation (1) and e_2 from equation (2) will be negatively correlated. First, the previous mechanism through v will still be in operation: profits will still depend positively on v [as in equation (11′)], and the factor share will still depend negatively on v [as in (12′)]. Second, since the presence of ϵ' biases the OLS estimate of β in (1) toward zero, some of the negative effect of ϵ on observed profits will be picked up by the error term e_1 in (1), so e_1 will be negatively correlated with ϵ. Therefore, because the factor share, and so e_2, will continue to be positively correlated with ϵ [as in (12′)], this second mechanism also induces a negative correlation between e_1 and e_2. The positive correlation between e_2 and ln W^* will then cause the SUR estimate of β to be biased downward, just as before.[7]

Conclusion

This comment uses Quiggin and Bui-Lan's hypothesis of large errors in measuring the wage to explain some of the phenomena observed in the profit function literature spawned by Lau and Yotopoulos (1972). Of course, measurement errors may not be the only possible explanation of this phenomena, and, in any case, the importance of measurement errors should vary from data set to data set. Nevertheless, a number of suggestions can be made on the basis of the results in this note. First, a significant negative coefficient on the wage in OLS estimates of the profit function should not be taken as evidence of the reliability of the data or model because such a coefficient can arise purely from measurement errors. Second, researchers should check for evidence of measurement errors. One such piece of evidence might be positive correlation between the error e_2 in equation (2) and the log observed wage because both should depend positively on the measurement error ϵ [see (12′); there will also be correlation between the wage and the factor share, however, if the true production function is not Cobb-Douglas]. Third, SUR estimates of the profit function should either not be used at all or should be used with extreme caution. Leaving aside the model developed in this comment, the consistency with which SUR estimates of the wage coefficient are less negative than the OLS estimates suggests that the assumptions of SUR are probably violated.

Finally, more work needs to be done to determine the importance of measurement and other errors (such as quality variation) in profit function studies and to develop consistent estimates in the face of these errors. A careful analysis of the error structure of equations (1) and (2), for example, should yield some information. In addition, Deaton's work, assuming all price variations in a given location are due either to quality variations or measurement errors, may suggest a fruitful direction for future research.[8]

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[7] One anonymous referee believes that this may be the mechanism which Quiggin and Bui-Lan had in mind, though their discussion is so brief that this is difficult to determine.

[8] Deaton's paper was brought to my attention by an anonymous referee. For further discussion, see Conlon.

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Assessing Strategies for Control of Irrigation-Induced Salinity in the Upper Colorado River Basin: Comment

Brandt K. Stevens and Henry J. Vaux, Jr.

In their analysis of the cost effectiveness and relative cost shares of alternative salinity control strategies in the Grand Valley, Gardner and Young (GY) inadequately address two issues. First, it has been shown that cost-effective input incentives require both a water tax and an irrigation system subsidy, irrespective of the consequences for cost shares (see references below). Second, by neglecting the income effect associated with the assignment of water quality entitlements to irrigators, *GY* may underestimate the resultant salt loads. This comment addresses these two issues in turn.

Cost-Effectiveness and Input-Based Incentives

A review of the findings of Holterman, Griffin and Bromley, and Stevens (1988) with respect to the cost effectiveness of input-based incentives is useful. In these models, pollution is produced jointly with output and is determined by $g(X_i)$, where X_i is a vector of $i = 1 \ldots m$ inputs. Some inputs increase pollution, such as irrigation water, and others abate pollution, such as additional capital in improved irrigation systems; therefore,

$$\partial g/\partial X_i \gtreqless 0.$$

Pollution-reducing input incentives, defined as the vector S_i, can include a water tax or a water conservation subsidy and an irrigation system subsidy. An irrigation system subsidy, consistent with GY's analysis, can be denoted by $S_i = \alpha_i P_i$, $0 \leq \alpha_i \leq 1$, where α_i is the government's percentage cost-share of an irrigation system loan payment. For a given vector of incentives, the distribution of entitlements, where the amount of the entitlement is given by X_i^0 for $i = 1 \ldots m$, encompasses a range of net payments from a pure subsidy to a pure tax (Griffin and Bromley, Mumy). Under the status quo, irrigators receive a n subsidy (X_i^0 equals current input use). Irrigators pa a net tax if all rights are assigned to downstream use (X_i^0 equals zero). For an allocation of entitlemen between these two extremes, irrigators and dow stream water users share entitlements and pollutic control costs.

Entitlements can be changed through negotiatio and/or legal proceedings which, in the GY case, wou involve Upper Colorado Basin irrigators, dow stream water users, and the federal governmen However, the process for changing entitlements is bo lengthy and unpredictable, so irrigators have a stro tendency to view present entitlements as fixed. E titlements should therefore be treated as given (Gri fin and Bromley).

For a competitive profit-maximizing firm, a set m influent incentives exists whose cost-effectivene is identical to that of an effluent incentive, S, at t same level of pollution control (Griffin and Bromle Stevens 1988), when

$$(1) \quad S_i = S(\partial g/\partial X_i);\ S_i \gtreqless 0 \text{ when } \partial g/\partial X_i \gtreqless 0 \quad \text{for } i = 1 \ldots r$$

Two conclusions can be drawn from equation (1 First, cost effectiveness is not related to the direc ness or indirectness of an incentive, as asserted GY (p. 43). The indirect policy can be as cost e fective as the direct policy when each input's influe incentive is determined by the product of the efflue incentive and each input's marginal contribution pollution generated.[1] Second, the sign of the inp incentive can be positive, negative or zero, depen ing on the marginal effect of the input on pollutio Thus, a cost-effective influent strategy for reduci salt loads to the Colorado River requires increasi the opportunity cost of irrigation water with either water tax or water conservation subsidy while s

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[1] Equation (1) assumes equal transactions costs for effluent a influent incentives. However, the criticism of GY's view of c effectiveness is valid because their empirical model also assum equal ($0) transactions costs. Both types of incentives may ha similar information requirements for implementation (Stevens 198 p. 290–91).

Equation (1) also applies for a multicrop model (Griffin a Bromley). Stevens' (1982) empirical analysis with a multicrop mo shows that, chosen correctly, an influent strategy results in the sa social cost as an effluent charge.

multaneously subsidizing irrigation system capital.[2]

Although the data in tables 2–4 of GY suggest that an effluent incentive is more cost effective than influent incentives, this apparent contradiction arises because the influent incentives chosen by GY cannot be cost effective (compared to the salt tax). For example, table 2 of their paper implicitly assumes that the marginal effect of irrigation water or irrigation system capital on pollution is nil because either S_1 (the water tax) = \$0 or S_2 (the irrigation system subsidy) = \$0. In table 4, the tax/subsidy policies indicate a nonzero marginal effect for irrigation water and irrigation system capital. However, this is insufficient to ensure cost effectiveness because the vector of cost-effective influent incentives is uniquely determined by each input's marginal contribution to pollution evaluated at the desired salt load reduction. Some tax/subsidy pairs in table 4 may be cost effective, but this cannot be true of all the policies presented. For example, if a tax/subsidy of \$14/40% is cost effective, a salt load reduction of more than 91,400 tons requires an increase in both incentives (a higher water tax and a larger subsidy), not an increase in just the irrigation subsidy.

The social losses from an inefficient set of influent incentives may be considerable. A conservative (but rough) estimate suggests that the social costs of achieving a desired salt load reduction may be 25%–100% higher because the influent incentives are improperly chosen. This estimate is based on a comparison of the total social costs of the salt taxes from table 2 and the block water tax/irrigation system subsidies in table 4. The comparison is necessarily rough because the salt load reductions are unequal for the two types of incentive mechanisms.

According to GY, the advantage of a simultaneous tax/subsidy strategy lies with its ability to change the distribution of costs. "Combining cost-sharing mechanisms into a 'carrot and stick' approach provides flexibility to cost distribution. We tested irrigation system subsidies with both salt and water taxes and water conservation subsidies with water taxes . . . nearly any local cost share can be achieved by varying the level of the 'carrot' and/or 'stick'. . . . Pragmatically, this flexibility in cost distribution may be worth some efficiency loss and additional administrative expense" (p. 45).

The review of cost-effective influent incentives demonstrates that this view is incorrect for two reasons. First, a cost-effective influent strategy requires a water tax (or water conservation subsidy) and an irrigation system subsidy, irrespective of the consequences for relative cost shares and regardless of the distribution of entitlements. An irrigation system subsidy/salt tax policy or a water conservation subsidy/water tax policy cannot be cost-effective. Second, no trade-off between the goal of an acceptable distribution of pollution control costs and cost-effectiveness is necessary. Policy makers can achieve any distribution of pollution control costs by varying X_i^0 from current usage levels to zero without changing the cost-effective influent incentives. Equation (1) shows the vector of incentives is independent of the distribution of entitlements. For example, using a given two-tiered water pricing structure, such as \$4.00/\$15.80 per acre-foot, a change in entitlements (and different cost shares) occurs when different quantities of water, such as 3.0/1.25 acre-feet and 2.5/1.75 acre-feet, are available at the two prices. Policy makers may choose to change the distribution of entitlements, through, for example, the EIS process, to make the salinity control policy politically acceptable to all parties, including rent-seeking irrigators.

Income Effects of Assigning Entitlements to Irrigators

The asymmetry of pollution taxes and pollution subsidies has been well-documented theoretically (Kamien, Schwartz, and Dolbear; Porter; Baumol and Oates). According to Baumol and Oates, when the marginal incentive of a pollution subsidy and a pollution tax are equal, the subsidy lowers the average cost of production, whereas the pollution tax raises average costs. The subsidy therefore encourages entry by new firms, increasing industry output while industry emissions may rise or fall (relative to preregulation emissions). Although these studies pertain to effluent incentives, a formal proof of the income-effect asymmetry for influent incentives can be readily constructed. Such a proof is omitted here for brevity.

The practical significance of the income-effect asymmetry from assigning entitlements partially or entirely to irrigators is unclear. GY's model could be revised to analyze this potential problem; the discussion here provides a rough estimate of the income effect's impact on salt loads.[3]

Empirically, the income asymmetry would manifest itself as an increase in irrigated acreage or a shift in crop mix or both.[4] Intuition suggests an increase in irrigated acreage or shifts in crop mix would take place on marginal quality cropland. Furthermore, Caswell and Zilberman show that when growers pay the full costs of water-conserving irrigation technol-

[2] The water tax and water conservation subsidy have the same marginal effect on irrigation water use. However, the water tax distributes entitlements to downstream water users and the water conservation subsidy maintains the status quo distribution of entitlements to irrigators.

The analysis is restricted to the two influent incentives analyzed by GY; but, strictly speaking, cost effectiveness may also require incentives for other inputs, for example, irrigation labor.

[3] Feinerman, Letey, and Vaux; and Caswell and Zilberman predict increasing yields from adoption of irrigation systems that apply water more precisely. Hence, the region's output will increase and we focus attention on salt loads.

[4] A shift in crop mix may occur if an increase in net rents alters growers' responses to risk. Given the per-acre deep percolation losses in Leathers and Young, shifts in crop mix are likely to have a small impact on salt loads. The discussion therefore focuses on an increase in irrigated acreage.

ogies, (a) these technologies will be adopted more frequently on lower quality cropland and (b) irrigable acreage will increase as lower quality cropland is drawn into production. Assuming profit-maximizing behavior, growers may increase irrigated acreage when net rents on new acreage equal or exceed net rents on marginal acreage now in production, subject to factors such as risk considerations and crop rotation patterns.[5]

There are three reasons an increase in irrigated acreage is plausible. First, the two block water tax/system subsidies in table 4 that result in a net subsidy payment increase net rents 8%–10% of base rents ($225,000 to $244,000). Second, growers will have unused water rights resulting from the adoption of improved irrigation systems. Under a water tax/irrigation system subsidy strategy, irrigation water use falls for two reasons—the tax makes some water rights uneconomical and some water is conserved via irrigation system improvements.[6] Table 2 in GY shows technological conservation of at least 22,000 acre-feet (10% of baseline water use) for a system subsidy equal to or greater than 50%. Third, Leathers and Young (p. 36) note that Grand Valley's acreage base could increase by as much as 15% from renovating the region's drainage system for salinity control purposes. The increase in annual net rents from a favorable distribution of entitlements could be used to finance regional drainage system improvements.

A rough estimate of the income-effect's impact on salt loads can be computed, assuming irrigated acreage increases 4%–15%. The lower bound of 4% is based on the assumption that annual fluctuations in irrigated acreage are representative of the effect of assigning entitlements to irrigators and is approximately equal to the standard deviation of the mean irrigated acreage.[7] Leathers and Young's estimate of the acreage increase resulting from regional drainage system improvements is utilized as the upper bound. The deep percolation coefficients in Leathers and Young vary by crop, with an average deep percolation equal to .59 acre-feet per acre. If an additional acre-foot of deep percolation adds 5 tons of salt to the Colorado River, total salt loads do not increase from 237,350 tons, but salt loads would be 5,900–22,125 tons higher than predicted by their model. The income effect's environmental impact is approximately 4%–16% of the predicted salt load reduction for the two policies that increase net rents.

If distributing entitlements partially or entirely to irrigators is necessary to ensure political acceptance of salinity control policies, policy makers may wish to mitigate the additional salt discharges. Regulators should consider a requirement that growers (a) not cultivate any additional acreage and maintain current crop rotation patterns or (b) accept a reduction in water deliveries consistent with the performance capabilities of new irrigation systems. An increase in irrigated acreage is directly prohibited by the first policy and indirectly prohibited by the second policy. In either case, if water is not a limiting resource under present conditions, water conserved by improved irrigation systems would not be used on existing acreage or new acreage, thus preventing increased drainage and salt loads.

Each requirement may be difficult to implement. For example, some mechanism to accommodate normal acreage fluctuations may be necessary. In addition, although the Food Security Act of 1985 contains a sodbuster/swampbuster provision, a separate program specifically for Grand Valley may be required because planting new alfalfa, an important Grand Valley crop, is not considered sodbusting. Present institutions will need to be modified to allow reduced water deliveries. Grand Valley has six water distribution entities which hold water rights in trust for irrigators served; irrigation entities that hold riparian rights have seniority. Additionally, as GY note, this water could be reappropriated by other (perhaps agricultural) Upper Basin users under the Colorado River Compact of 1922. In spite of these potential problems, a reduction in water deliveries would provide a strong incentive for growers to manage improved irrigation technology to its full potential, ensuring that actual salt load reductions match policy makers' expectations.[8]

Conclusion

It is important to understand how the distribution of pollution control costs is affected by the distribution of entitlements. Buchanan and Tullock have shown that polluters tend to oppose the use of market incentives as a pollution control strategy because of incentive payments to environmental regulators. Altering the distribution of entitlements can reduce (total) incentive payments markedly, thereby providing some measure of political acceptability for incentive strategies. This comment demonstrates that whatever the distribution of pollution control costs that all parties would find acceptable, the allocation of entitlements necessary to achieve the desired cost-shares and the

[5] Growers may have criteria other than net rents on marginal acreage, or may face other constraints, that determine when and how much additional acreage would be planted as a result of a favorable distribution of entitlements.

[6] If growers continue to purchase their full water allocation, the cost savings from adopting improved irrigation systems would be reduced. However, table 2, part A, shows that the labor cost reduction from better irrigation systems is larger than irrigators' share of new system costs for any subsidy greater than 30%. Thus, growers still have an incentive to adopt (subsidized) irrigation systems even if they use their full water allocation.

[7] The mean irrigated acreage was computed from U.S. Bureau of Reclamation acreage data, 1975–84, and adjusted for the crop acreage base used in GY's model. The standard deviation of the mean acreage (after acreage base adjustment) is 2,039 acres.

[8] As noted, this technologically surplus water results from the adoption of improved irrigation systems. Because growers have already received an incentive—the irrigation system subsidy—for this water, selling diversion rights to downstream beneficiaries is inconsistent with the cost-effective influent incentives from (1).

cost-effective influent incentives are independent, not conflicting, policy problems. When entitlements are distributed such that irrigators receive net payments, an income effect asymmetry would occur. In this specific case, the potential of the income effect appears modest. Nonetheless, policy makers should be aware of this potential problem and may wish to consider preventive measures.

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Assessing Strategies for Control of Irrigation-Induced Salinity in the Upper Colorado River Basin: Reply

Robert A. Young, Richard L. Gardner, and Edward W. Sparling

Stevens and Vaux (SV) raise two issues. First, they remind us that the cost effectiveness of an input (or influent) charge for pollution control can be identical to that of an effluent incentive at the same level of pollution control. Second, they contend that by not accounting for the income effect of subsidy approaches to pollution control, we may underestimate the resultant salt loads.

With regard to the first point, we agree that in a first-best neoclassical world modeled with continuously differentiable functions, the result they cite would hold. Central to the whole problem of nonpoint pollution is the impracticality of accurately measuring effluent. In a first-best world, and where economic efficiency is the sole objective, the effluent tax is for many analysts, the policy instrument of choice. However, given the difficulty of measuring effluent, practical policy analysis shifts attention to input incentives, on the assumption that certain inputs are both easily monitored and highly correlated with effluent.

An ideal input-based incentive scheme would require taxes or subsidies on all inputs affecting salt discharges. However, monitoring some important inputs, including management, labor and certain forms of capital, would be nearly as difficult as would keeping track of nonpoint salt discharges. Moreover, identification of an optimal incentive set would require precise knowledge of all transformations relating inputs to both outputs and discharges and of how risk enters into the producer's objective function.

Not having the resources to provide the ideal solution, we developed an admittedly second-best linear programming model that attempted to capture the relationships as well as possible. Since the typical farming patterns involves multiple crops, producer risk aversion is incorporated into the model with flexibility constraints. In addition, our model did not explicitly include labor and capital as variable inputs. Rather, their costs were deducted from revenues in the objective function.

In our study, the distribution of costs is equally important as economic efficiency. Hence, our strategy of analysis was to assess the cost effectiveness and distributional implications of a range of plausible policy options. In the process, we were willing to consider less than optimally efficient strategies. While we could have devised "efficient" influent incentive schemes, we did not do so, given the objective of our modeling exercise and the nature of our model. Because we were interested in representing workable incentives in the context of a second-best economic and policy environment, we made no attempt to construct first-best tax/subsidy schemes. It is certainly true that some of our incentive schemes were "inefficient," but that inefficiency is a cost of a second-best incentive scheme. Given these considerations, we feel no need to concede that our results provide other than what we sought: practical implications of plausible policies in an imperfect world.

The second point made by SV suggests that our analysis should be extended to consider "income effects" arising from of public subsidies to control pollutant emissions. By lowering the average cost of production, a subsidy may encourage entry by new firms or expansion by existing firms. Because of this potential expansion, total emissions may not fall by as much from a subsidy as expected. SV go on to acknowledge that "the practical significance of the income-effect asymmetry from assigning entitlements partially or entirely to irrigators is unclear." We fully agree. While we recognize the theoretical point, we would go further and say the point has little practical significance in our study area. First, the annual net rents would increase by less than $5 per acre. There is no particular reason to suppose that producers (who in this case are also households) would choose to invest that small amount to irrigate new lands rather than augmenting family consumption or paying off bankers. Second, even if producers considered so investing it, the minimal potential returns to new irrigated lands would be an effective deterrent. (The existence of positive net rents in the current situation is based on the fact that the presently irrigated area was largely financed by long since written-off public capital. New public subsidy to further irrigation development, while not inconceivable, seems unlikely.)

The length of SV's comment (more than half as long as our original article) may suggest to the reader that our policy conclusions are seriously damaged. We wish to conclude by reiterating that this is not the case. Our studies of the Colorado River Salinity Program can be encapsulated by these points. First,

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in keeping with the tradition of western water policy, the economic benefits claimed for the federal salinity control program are significantly overstated, and the program is questionable on economic efficiency grounds. Second, the least-costly method of achieving significant salinity control in the Upper Colorado Basin is by retiring irrigated lands. Finally, the existing distribution of entitlements in the basin (which can be encapsulated as: The upper basin producers are entitled to continue to irrigate and discharge salt; the lower basin water users are entitled to improved water quality; and the federal taxpayer is entitled to pay the bill) warrants careful public reconsideration.

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Separability Testing in Production Economics: Comment

Quirino Paris, Kenneth A. Foster, and Richard D. Green

Pope and Hallam (PH) proposed a test for indirect separability based on the rank of an appropriately defined matrix involving the bordered Hessian of the production function. This test is interesting and important, but its presentation obscures the main idea because the discussion, in the context of flexible functional forms, is marred by a crucial error. Blackorby, Primont, and Russell showed that a test for weak separability of flexible functional forms imposes strong and unwanted restrictions on a model's structure. After the publication of their paper, the consensus has been that a test for weak separability of flexible functional forms cannot be performed with the available functions. PH refer to this issue by stating: "This (test) moderates in some cases the criticism by Blackorby, Primont, and Russell" (p. 143). The reader is tantalized by this statement, but the rest of the paper does not shed any further light upon it.

PH discuss necessary and sufficient rank conditions for indirect separability but present also a lengthy elaboration of a necessary condition. The former set of conditions obviously provides a stronger test, and thus we focus our discussion upon it. Furthermore, PH's necessary rank condition as applied to the empirical example is wrongly stated and is inferior with respect to the stronger test.

We think that the contribution of PH can be stated in the following terms: The principal interest in the rank condition rests upon the possibility of testing the necessary and sufficient conditions for indirect separability. When not rejected, PH's rank condition, rank $[f_{\alpha\alpha}xf_{\alpha\alpha}](N_s, N_s^\theta) = 1$, implies indirect separability and, at least in two cases (generalized Leontief and quadratic functions), does not imply direct separability. Conversely, (in flexible functional forms), direct separability implies the rank condition for indirect separability, and this is the reason why this second test is subject to the criticism of Blackorby, Primont, and Russell. Thus, the rank condition applied to dual functions is noteworthy. However, its application in the context of flexible functional forms suggests that, for the translog function, its test is equivalent to the separability test originally proposed by Berndt and Christensen while, in the case of the generalized Leontief and quadratic functions, the two tests are substantially different. The numerical example chosen by PH is not suitable for illustrating the working of the necessary and sufficient rank condition which, furthermore, is erroneously implemented. The interesting question, therefore, is, are there other flexible functional forms (aside from the generalized Leontief and quadratic functions) for which the rank condition for indirect separability does not coincide with the conditions for direct separability? An answer to this question is conjectured in the conclusion.

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The Rank Condition and Flexible Functional Forms

The discussion of page 148 is largely mistaken because an error of omission was made in computing the second derivatives of the general flexible functional form:

$$(1) \quad g(z) = \alpha_0 + \sum_i \alpha_i f_i(z_i) + \frac{1}{2}\sum_i \sum_j B_{ij} f_i(z_i) f_j(z_j), \quad B_{ij} = B_{ji}.$$

At the top of page 148, PH write the second derivative as

$$(2) \quad \frac{\partial^2 g}{\partial z_i \partial z_k} = B_{ik}\frac{\partial f_i}{\partial z_i}\frac{\partial f_k}{\partial z_k}.$$

Clearly, this second derivative is valid only for $i \neq k$ while the missing part is the derivative for $i = k$; that is,

$$(3) \quad \frac{\partial^2 g}{\partial z_i \partial z_i} = \frac{\partial^2 f_i}{\partial z_i \partial z_i}\left[\alpha_i + \sum_j B_{ij} f_j(z_j)\right] + B_{ii}\frac{\partial f_i}{\partial z_i}\frac{\partial f_i}{\partial z_i}.$$

The first term on the right-hand side (RHS) contains the α-parameters which are missing in PH's discussion of the necessary and sufficient rank condition. The representation of the rank condition for indirect separability, rank $[g_{zz}z\, g_{zz}](N_s, N_s^\theta) = 1$, where $N_s = (2, 3)$ and $N_s^\theta = (0, 1)$, reduces to the following:

$$(4) \quad \frac{\partial f_1}{\partial z_1}\frac{\partial f_2}{\partial z_2}\frac{\partial f_3}{\partial z_3}\sum_k [B_{31}B_{2k} - B_{21}B_{3k}]\frac{\partial f_k}{\partial z_k} z_k + \frac{\partial f_1}{\partial z_1}\left[\frac{\partial f_3}{\partial z_3}\frac{\partial^2 f_2}{\partial z_2 \partial z_2} z_2 B_{31}\alpha_2 - B_{21}\alpha_3 \frac{\partial f_2}{\partial z_2}\frac{\partial^2 f_3}{\partial z_3 \partial z_3} z_3\right] + \frac{\partial f_1}{\partial z_1}\sum_k \left[\frac{\partial f_3}{\partial z_3}\frac{\partial^2 f_2}{\partial z_2 \partial z_2} z_2 B_{31}B_{2k} - B_{21}B_{3k}\frac{\partial f_2}{\partial z_2}\frac{\partial^2 f_3}{\partial z_3 \partial z_3} z_3\right] f_k(z_k) = 0.$$

This general expression for the rank condition of indirect separability takes on different representations when applied to various members of the flexible functional family. For example, for the translog function, $f_i(z_i) = \log z_i$, the rank condition becomes

$$(5)\quad \frac{1}{z_1}\frac{1}{z_2}\frac{1}{z_3}\sum_k [B_{31}B_{2k} - B_{21}B_{3k}]\frac{1}{z_k} z_k + \frac{1}{z_1}\left[\frac{1}{z_3}\left(-\frac{1}{z_2^2}\right)z_2B_{31}\alpha_2 - B_{21}\alpha_3\frac{1}{z_2}\left(-\frac{1}{z_3^2}\right)z_3\right] + \frac{1}{z_1}\sum_k\left[\frac{1}{z_3}\left(-\frac{1}{z_2^2}\right)z_2B_{31}B_{2k} - B_{21}B_{3k}\frac{1}{z_2}\left(-\frac{1}{z_3^2}\right)z_3\right]\log z_k = 0.$$

First, it is clear that (after factoring out the common terms) the arguments in the first and third squared brackets are identical. Secondly, for the global validity of this condition, each of the three terms must be set equal to zero, thus obtaining

$$(6a)\quad B_{31}\alpha_2 - B_{21}\alpha_3 = 0$$

$$(6b)\quad B_{31}B_{2k} - B_{21}B_{3k} = 0,\quad k = 1, 2, 3,$$

which are exactly the conditions for direct separability as given by Blackorby, Primont, and Russell and also reported by PH (p. 148). Notice that, under global validity of the rank condition, the first term of (5) becomes

$$(7)\quad B_{31}\left[\sum_k B_{2k}\right] - B_{21}\left[\sum_k B_{3k}\right] = 0,$$

but this condition is either implied by (6b) or by the homogeneity property customarily imposed on flexible functional forms. Hence, in the case of the translog function, the rank condition of Pope and Hallam is of no help in alleviating the "unwanted restrictions" detected by Blackorby, Primont, and Russell.

Consider, now, the case of the generalized Leontief function for which $f_i(z_i) = z_i^{.5}$. The rank condition for indirect separability takes on the following representation:

$$(8)\quad \left(\frac{1}{2}z_1^{-.5}\right)\left(\frac{1}{2}z_2^{-.5}\right)\left(\frac{1}{2}z_3^{-.5}\right)\sum_k [B_{31}B_{2k} - B_{21}B_{3k}]\left(\frac{1}{2}z_k^{-.5}\right)z_k + \left(\frac{1}{2}z_1^{-.5}\right)\left[\left(\frac{1}{2}z_3^{-.5}\right)\cdot\left(-\frac{1}{4}z_2^{-1.5}\right)z_2B_{31}\alpha_2 - B_{21}\alpha_3\left(\frac{1}{2}z_2^{-.5}\right)\cdot\left(-\frac{1}{4}z_3^{-1.5}\right)z_3\right] + \left(\frac{1}{2}z_1^{-.5}\right)\sum_k\left[\left(\frac{1}{2}z_3^{-.5}\right)\cdot\left(-\frac{1}{4}z_2^{-1.5}\right)z_2B_{31}B_{2k} - B_{21}B_{3k}\left(\frac{1}{2}z_2^{-.5}\right)\cdot\left(-\frac{1}{4}z_3^{-1.5}\right)z_3\right]z_k^{.5} = 0.$$

After obvious simplifications, the first and third terms are identical but of opposite sign and, therefore, drop out of the rank condition altogether. Therefore, for the global validity of such a condition in the case of the generalized Leontief function, we simply have

$$(9)\quad B_{31}\alpha_2 - B_{21}\alpha_3 = 0.$$

As a third example, let us consider the quadratic function with $f_i(z_i) = z_i$. Then, the rank condition for indirect separability simplifies to

$$(10)\quad B_{31}B_{2k} - B_{21}B_{3k} = 0,\quad k = 1, 2, 3.$$

This expression is obtained from the first term of (4), while the other two terms vanish since the second derivative of $f_i(z_i)$ is identically equal to zero.

These results allow the testing of indirect separability associated with generalized Leontief and quadratic functions while breaking away from the "unwanted restrictions" detected by Blackorby, Primont, and Russell for the translog function and support Pope and Hallam's claim that "this (test) moderates in some cases the criticism by Blackorby, Primont and Russell" (p. 143).

Test for Indirect Separability

In order to illustrate their methodological result, PH chose to estimate a generalized Leontief function involving cotton lint as a dependent variable (y), and plant spacing (SP), irrigation water (WA), and nitrogen (NI) as inputs. For the purpose of clarity, this type of production function is specified as

$$(11)\quad y = a_0 + a_1SP^{.5} + a_2WA^{.5} + a_3NI^{.5} + b_{11}SP + 2b_{12}SP^{.5}WA^{.5} + 2b_{13}SP^{.5}NI^{.5} + b_{22}WA + 2b_{23}WA^{.5}NI^{.5} + b_{33}NI + u.$$

PH wished to test whether "nitrogen and water form a group which is nonadditively separable from spacing (p. 150)." For verifying the indirect separability of the associated dual function, they indicated that the relevant condition is

$$(12)\quad rank\begin{bmatrix} b_{12} & b_{22} & b_{23} \\ b_{13} & b_{23} & b_{33} \end{bmatrix} = 1,$$

which implies two restrictions: $b_{12}b_{23} - b_{13}b_{22} = b_{22}b_{33} - b_{23}^2 = 0$. As indicated above, however, a direct application of the rank condition to a generalized Leontief function with partition $N_s = (2, 3)$ and $N_s^0 = (0, 1)$, produces the following restriction:

$$(13)\quad rank\begin{bmatrix} -a_2WA^{-.5}/4 & b_{12}SP^{-.5}WA^{-.5}/2 \\ -a_3NI^{-.5}/4 & b_{13}SP^{-.5}NI^{-.5}/2 \end{bmatrix} = 1,$$

requiring simply that $a_2b_{13} = a_3b_{12}$ for the global validity of the condition. The discrepancy with PH's choice of implementation is based upon the erroneous second derivative. As a consequence, a rank condition test based on (12) is a chi-square variable with two degrees of freedom, while the same test based

on (13) has only one degree of freedom. We have performed an empirical verification that a generalized Leontief specification admits the possibility of indirect separability while rejecting direct separability. The empirical illustration of PH obscured this important point.

Conclusion

The implementation of Pope and Hallam's rank condition on a generalized Leontief function takes on a simpler specification than that suggested in their paper. Although for the translog functional form, the rank condition expresses restrictions which are identical to the direct separability conditions, the generalized Leontief and quadratic functions allow for a meaningful application of the rank condition. Thus, the obvious question, anticipated in the introduction, is whether other flexible functional forms can join the generalized Leontief and quadratic functions in that happy endeavor. The answer appears to be negative. The generalized Leontief and quadratic functions seem to "moderate the criticism of Blackorby, Primont, and Russell" only because each of them represents a case of singularity where two of the terms in equation (4) are eliminated. No other mean function of order ρ, ($f_i(z_i) = z_i^{\rho}$), generates similar cancellation, and its rank condition for indirect separability coincides with the conditions for direct separability.

For the moment, a conclusion about PH's rank condition is intimately tied to the structure of present-day flexible functional forms: the known forms are "separability-inflexible" and (except for the generalized Leontief and quadratic functions) PH's rank condition for indirect separability is another way of packaging the conditions for direct separability. Hence, the empirical resolution of the weak separability issue must be directed toward a search of functional forms which are "separability-flexible." When those functions will be available, we conjecture that weak and direct separability will be testable without restrictions. The corresponding dual functions will likely be of unknown form, as is the case for the current flexible functions. At that time, the full potential of PH's rank condition will also become transparent since it will be possible to test for weak separability of the indirect functions without imposing any restriction on the primal model.

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Books Reviewed

Retrospective Review

Ciriacy-Wantrup, S. V. *Resource Conservation: Economics and Policies*. Berkeley and Los Angeles: University of California Press, 1952, 395 pp.

Since my tenure as a doctoral student at Berkeley (1958–61), I have been fascinated with the persona of Siegfried von Ciriacy-Wantrup, or "The Baron," as he was furtively referred to among the graduate students upon the infrequent occasions he was sighted in the halls moving directly to or from his office. Only a few students were involved in natural resources economics in the Agricultural Economics Department at Berkeley in those days. The Baron did not engage himself with those who were not, student or otherwise. He did not leave his office even to fetch a book or article from our convenient departmental library. The material was brought to him and handed in through the partially opened door. One did not enter without an invitation.

My field of concentration was called farm and ranch management. It was just evolving into production economics. We read Heady and articles on econometrics and linear programming. How I got into Wantrup's evening seminar on natural resources I have no idea. I entered confused and frightened. Wantrup turned out to be a gentleman of the old school, courteous and correct. Class, like his book *Resource Conservation,* was a groping to understand, to define in language, and to be educated. It was an intellectual experience. It was the only class I attended while at Berkeley that I realized that I did not understand and actively disliked. We did not read *Resource Conservation* for class. Wantrup assumed that if you had any intellectual pretensions you would read it on your own. I did, but found it too amorphous and nondirective.

It was only over time that I slowly evolved into being known as a natural resources economist. In Arizona, where I joined the University of Arizona faculty in 1961, water, a natural resource, is required to be applied artificially if any crops are to be grown. Cattle graze the public lands and are competitive (or complementary) with use of the lands for other products such as timber, wildlife, hunting, camping, and water for offsite use. Many of these products are nonmarket goods, or at least not sold in competitive markets. In studying the field of farm and ranch management, I entered the field of natural resources by the side door, at first without recognizing that I had done so.

Having become a natural resources economist, did I return to read and reread *Resource Conservation?* No. And despite the fact that Ciriacy-Wantrup ranked about fifteenth among the authors most cited as references in the *AJAE* during the period 1959–68 (Finley and Barger, 1973), I personally did not find my colleagues on the Western Agricultural Economics Research Council (WAERC) Natural Resources, Water Resources, and Range Committees using *Resource Conservation*. The field of natural resources was developing rapidly. The interest was in development of theory explicated in mathematical terms and in the application of empirical tools. There was little need for more than a passing reference to Wantrup as having mentioned the subject. I suspect that *Resource Conservation,* where referenced, had not been carefully read. An obvious exception to this generalization was my postgraduate mentor at the University of Arizona, M. M. Kelso, whose well-underlined copy I am now perusing. But Kelso, like Wantrup, was of a different age of agricultural and natural resource economist. He was trained in the appreciation of expressing theoretical concepts in nonmathematical language, and in treating real-life institutions as variables in the analytical framework of his analysis.

This rather lengthy preface leads me to the basic questions of this retrospective review. What does *Resource Conservation* contain, and are the contents relevant to issues of today? The answers are that as a basic frame of reference for conservation issues, *Resource Conservation* is as timely today as when published in 1952; and, as has been said of Alfred Marshall's *Principles of Economics* (1890), "it is all in Wantrup." The background for most current analyses are contained therein. Few answers are contained, however. As in Wantrup's 1958 seminar, there are only issues to be investigated. The effects of any policy may vary widely under given circumstances. Our job is to integrate specific circumstances with general theory.

Resource Conservation begins with an extensive section on definition and classification. As Kemeny has commented, definition and classification are extremely useful and necessary (if boring) early steps in a developing science. The tendency, particularly among social scientists who naturally desire useful social applications, is to rush into analysis before the problem has been properly defined.

Wantrup recognized that the word "conservation" has many contradictory definitions among many people. He defines the study of conservation simply as the quest "to understand the factors that affect the distribution of resource use over time, to inquire into the objectives of public policy with respect to this distribution, and to seek tools with which to implement policy objectives" (p. 12). Optimal distribution

of use over time will vary for different classes of resources; for example, for stocks versus flows, for exhaustible versus inexhaustible, and for primary versus secondary resources.

Given that conservation is about intertemporal distribution, the important analytical variables are interest rates, risk, and risk preference. These variables will be affected by all manner of private and public institutions, including, but not limited to, prices, incomes, price and income support policies, property rights, tenency rules, credit, taxation, and market form. Wantrup devoted chapters to each variable, examining the possibilities of complex interactions between the various forces. Of particular importance in Wantrup's view are the institutional effects on the security and flexibility of resource rights.

An earlier review commented on an apparent inconsistency in definition (Murdock 1953). Conservation is defined as the redistribution of a use "in the direction of the future," while depletion is "in the direction of the present" (p. 51). Value is not a component of the definition. Then, the optimum state of conservation is defined "as that time distribution of use rates that maximizes the present value of the flow of (expected) net revenue," a rule offered for both a private planning agent and for society in general. The argument is that the determining factor is value, an element absent from the definition. It appeared that Wantrup was avoiding explaining resource valuation by moving from one criterion (time) to the other (value). My reading of Wantrup simply is that while, as an economist, he stands up for the optimization rule, he recognized the complexity of selecting the correct rate of time preference, and opts for "the simplifications and approximations that are needed in reality" (p. 21). Directions toward conservation or depletion may be all we can hope for in practicality.

Castle et al., in the AAEA *Survey of Agricultural Economics Literature,* comment that Ciriacy-Wantrup was at least two decades ahead of most workers in agricultural and natural resources economics in treating institutions as explicit variables in his analytical framework. He was ahead in other areas as well. He had a clear recognition of the values for nonmarket goods and suggested that they could be obtained by questionnaire using hypothetical situations (now known as contingent valuation). He recognized that prices merely are normative expressions of values, and that because of the inequities in income distribution there are problems with the concept of consumer sovereignty. Further, resource conservation policies affect the distribution, just as the distribution affects policies.

Given the complexities of the world, Wantrup concludes that "the state in which social net revenues are maximized over time—is of only limited practical interest" (p. 249). The practical goal in conservation policy is a step-by-step improvement of the existing time distribution of use rates—analysis of policies at the margin. As a first approximation, and to guard against irreversible error, he offers the concept of a "safe minimum standard of conservation" (p. 253). Just as the possibilities for substitution and flexibility always provide for least cost solutions in private economics, the maintenance of a safe minimum standard is viewed as an increase in flexibility in the continuing development of society. "Costs of maintaining the safe minimum standard are not only small in absolute amount, but very small relative to the loss which is being guarded against, a decrease of flexibility (for) society" (p. 255). This standard may be expressed in any of a number of ways, but must be designed to avoid a use rate that avoids economic irreversibility. Thus, the standard could change over time. This standard is a conservative measure in that it is less than any higher (possibily optimum) state of conservation. Above the minimum standard, free private initiative may be allowed to operate. Minimal influence with private enterprise will occur.

The final three chapters focus on the tools (institutions) with which to implement conservation policy. They are a thorough survey of the then current and historical methods and economic conditions affecting conservation; but, as earlier reviewers commented, they are less imaginative and of less analytical interest than the first three-quarters of the book. Wantrup shows through as an idealist here. Everyone—resource users and nonuser alike—should be educated as to the complexities of resource use. Each policy should be coordinated with every other policy. But Wantrup is a realist as well as an idealist. Results from education alone will be small if economic and institutional factors stand in the way. The basic problem is that all methods of conservation policy have good points for some and bad points for others. Thus, the basic need for simple, practical, safe minimum standards of use arise. This final result is not eloquent economics, but the arguments presented in getting there are. *Resource Conservation* is well worth revisiting.

There was another personal experience relative to this gentle, idealistic scholar that I found rather poignant. Late in 1980, about a year after Ciriacy-Wantrup's death, I was visiting the Berkeley Department of Agricultural Economics in order to give a seminar on a subject in natural resources. As I was to be there for a couple of days and make myself available for discussions with students, the department decided that I should be given a temporary office. Professor Wantrup's office was empty, and because I was a visiting natural resources economist, it was made available for my use. There was quite a fuss as the secretarial staff searched for a key and started to make arrangements for a work-study student to clean off the desk and bookshelves. I assured them that the key was enough and went to the room.

Nothing had been touched since Wantrup's death. His desk was in orderly shape as he had left it. His umbrella and rubber overshoes were there in the corner. *Resource Conservation* was on a nearby shelf, and I began to browse through it for the second time. It was a restful and productive two days. Some very

pleasant and earnest graduate students, who were too new to have known Wantrup, made visits to my office. But all members of the departmental staff who had need for any dealings with me did so from the hallway, across the doorstep. They resolutely would not enter the office. For them, Professor Wantrup was still there.

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New Reviews

Barbier, Edward B. *Economics, Natural Resources Scarcity and Development: Conventional and Alternative Views*. London: Earthscan Publications Limited, 1989, xvii + 223 pp., price unknown.

Current resource issues such as the greenhouse effect, deforestation, and the sustainability of current agricultural systems have caused economists to reevaluate the current treatment of natural resource issues and to look for an expanded framework which encompasses the multiple demands placed upon resources. This book provides a timely discussion of the limitations of the current treatment of resource problems and provides "a new way of looking at the inter-relationship between the economics of sustainable development" (p. xvi). The alternative view is offered not "as a replacement for conventional environmental and resource economics . . . , but as a necessary extension . . . into explicit analysis of environmental degradation and economic consequence of ecological disruption" (p. 92). The text introduces a conceptual framework in which constraints are placed upon economic systems through short-run environmental conditions which serve as an input to productive and consumptive activities, and the long-run potential for irreversible long-run environmental degradation.

The book has eight chapters that can be grouped into two sections. The first four chapters provide a discussion of the evolution of resource economics, while the last four chapters introduce and apply an alternative approach to resource economics. The book begins with a review of the treatment of resource issues by the classical economists. Chapter 2 supplies an overview of the contributions of conservationism, ecology, and thermodynamics. Chapters 3 and 4 discuss the neoclassical treatment of optimal depletion and externalities. Each of these chapters concludes with a discussion of the limitations associated with each treatment. These chapters provide a thorough and well-documented review of the evolution of the economic treatment of resource issues and the need for a broadened perspective to deal with emerging resource concerns.

Chapter 5 introduces an alternative model developed by the author which incorporates environmental quality constraints. Chapters 6 and 7 present the author's application of the alternative model to three problems: deforestation of the Amazon Basin, the greenhouse effect, and soil erosion in Indonesia. Chapter 8 provides a summary of the arguments presented and the need for alternative economic approaches to resource issues.

The thrust of the book is that economic and environmental systems are integrally intertwined; therefore, failure to incorporate the effect of environmental degradation on the sustainability of environmental systems will result in an analysis unable to capture fully the consequences of environmental degradation on social production and consumption and the sustainability of economic systems. Because the neoclassical treatment of resource issues has tended to treat optimal resource use and assimilative capacity of environmental systems as separate problems, the current treatment of resource problems needs to be extended to integrate resource use and environmental degradation.

In the first five chapters the author makes a sound case for the need to extend conventional economic treatment of resource issues and introduces a conceptual model to provide such an extension; however, the presentation falters in the ensuing chapters during the application of the new framework. In these chapters the author demonstrates his knowledge of the issues and policies involved but fails to demonstrate that the new framework provides a substantial improvement over previous treatments. Here, the author does not follow his own paradigm of fully integrating economic and environmental systems but, instead, paints a broad picture of the unsustainability of current economic practices given the ecological damage resulting from the bane of resource economics, incomplete information concerning the ecological and nonmarket economic ramifications of current practices. However, a more thorough integration of the economic and environmental systems would have resulted in a clearer presentation of the author's ideas.

Economists seeking an alternative approach to the interaction between economic and environmental systems will find the author's exposition an interesting and timely contribution, but his application is wanting.

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Barry, Peter J., John A. Hopkin, and C. B. Baker. *Financial Management in Agriculture*, 4th ed. Danville IL: Interstate Printers and Publishers, 1988. xii + 500 pp., $24.95.

This fourth edition reflects refinements to the previous editions and updates the empirical data, examples, and organization. It remains a text focused upon financial management, organized into nineteen chapters and six sections. The sections cover nature and scope of financial management, measurement and analysis of financial performance, concepts of leverage, risk and liquidity, valuation and decision making, financial intermediaries, and related topics.

The authors consider the book to be targeted primarily to an audience of advanced undergraduate and beginning graduate students and to a lesser degree to others interested in understanding the application of economic and business principles in the financing of farm production.

I found the text to be quite readable but not exciting. I tried to picture myself as a student again and wondered if I could overcome the many external distractions long enough to get to each chapter's concluding "topics for discussion," where both significance and substance can be found. It takes effort. I do not consider this a shortcoming of this book as much as a general indictment of many college textbooks and some wishful thinking that more challenge could be incorporated with the concepts and principles.

Experiencing the credit problems of the 1980s drove me to chapter 3 on leverage and financial risk. The chapter is good and the discussion questions are excellent vehicles for providing a framework for classroom discussion, learning reinforcement, and illustration. Unfortunately the text on page 121 also is true: "Smaller-scale firms . . . main sources of equity capital is retained earnings whose costs are difficult to measure, whose amounts are subject to high uncertainty, and whose rates of growth often are not fast enough to finance large investments," thus heavy reliance on borrowing and land appreciation for unrealized capital gain. Applying concepts in practice, either classroom or business, is rarely easy. I would like to see use of some real-life, mini-case problems inserted in chapters such as this. I think it would help close a gap of understanding and application for many students.

Chapter 9 addresses the time value of money. It is straightforward and a traditional approach to net present value. Farm borrowers seem always to struggle with the same concept when applied not to investments but to the use of debt. The fact that interest is just the cost of using someone else's money for a specified period of time carries neither intrinsic rights nor borrower rights; yet, much of agricultural finance today has become intertwined with social goals not normally found in analytical equations. There may be a place for addressing in a text such as this some of the social issues that arise in the agricultural sector because of its importance to national welfare, unique appetite for debt capital, complicated family and business structure, and lumpy and often nonliquid asset structure. Chapter 17 addresses policy issues affecting agricultural credit markets but mostly from an economic efficiency perspective. There is little mention of a social dimension of policy, and yet it seems to be profoundly at the forefront of national policy debate.

As a book on financial management in agriculture, the text is strongest where it should be, in developing the underpinning theory and concepts of financial management. It is weakest in presenting applied material which students can more easily relate to practice. For example, new employees as beginning loan officers, most of whom have had finance courses, rarely have a good understanding of accounting and legal issues in finance. Legal issues have increased in importance over time as the Uniform Commercial Code (p. 352) has been supplemented with Truth-in-Lending (p. 319). Bankruptcy Code (p. 372), and various laws on borrower rights including equal credit opportunity and fair credit practices. Because many farm businesses also use credit for consumer purposes, the financing of agriculture is seldom a pure agricultural transaction. It might be helpful to pull several of these related topics together in a more prominent chapter with legal instruments, security recordings, and lien perfection. Likewise, the complexity of farm business accounting deserves more than the introductory disclaimer (pp. 29–30) and the simplified financial statement development of chapter 3. I would not expect this text to be an accounting course; but the failure to understand inventory, depreciation, and other cash accounting distortions continues to produce many misleading financial measures and erroneous decisions in farm financial management. Perhaps an expanded appendix on accrual accounting issues would complement this chapter.

Section five focuses on financial intermediation and takes a traditional institutional approach. It is accorded about the right amount of space and importance to complete the picture. *Financial Management in Agriculture* covers a broad scope of material from basic economic and business principles and concepts to analytical techniques to institutions to tax and legal issues to national policy making. It should be a versatile text for college courses.

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Anne Booth. *Agricultural Development in Indonesia.* Sydney, Australia: Allen and Unwin, 1988, vii + 295 pp., price unknown.

Despite serving as the original stimulus for dual economy models of development, Indonesia's agricultural economy has attracted remarkably little notice in the modern development literature. This oversight is even more remarkable in view of the success story to be told. Both relative to its own historical performance and to the performance of most other countries in the past quarter century, Indonesia's agricultural sector has shown steady and rapid growth. And contrary to widespread expectations in the late 1960s, based on Geertz's views on shared poverty on Java and progressive limitations on capacity to absorb labor in its involuted rice culture, the rapid growth in agricultural output has been accompanied by a sharp reduction in poverty. Surely it is important to understand the causes of such a surprising success story in the world's fifth most populous nation.

Anne Booth understands that there is a paradox to explain and that this complicates the story considerably. First, the roots of both the early pessimism and the modern success are deeply historical, and Booth's analysis incorporates a detailed and masterful survey of the Dutch colonial record, now accessible to English-speaking scholars largely through her efforts. Second, Boeke's explanation of the limited response of Javanese peasants to colonial efforts to improve agriculture through irrigation and extension of modern cultural practices strongly conditioned how early development economists perceived the role of traditional agricultural sectors in the modernization process. Dualism, especially in labor markets, provided much of the rationale for the anti-agricultural biases of so many development plans in the 1950s and 1960s, including those of Indonesia. Models and ideas can have a permanence and influence far beyond the realities that (may have) once generated them, and this perserverance carries directly into development policies. At a time when many analysts and policy makers were worried about agricultural stagnation and immiseration, Indonesian farmers were busy expanding output by using new technology, more purchased inputs (including labor), and increased specialization made possible by far greater participation in rural product markets, which had been stabilized through active government price policies.

The third complexity that Booth recognizes, and the ultimate strength of the book, is that Indonesia's agricultural success story is set squarely in a supportive macroeconomic environment. Although she delineates in sharp detail the elements of the agricultural development efforts of the New Order government under President Suharto, Booth never loses sight of the policy context in which those elements were designed and implemented. The real test of this relationship, of course, is how the agricultural economy responded to the two oil shocks in 1973 and 1979. Indonesia suffered a severe case of Dutch Disease between 1973 and 1978, but many analysts were surprised to find that the most serious problems occurred in the rural sector, rather than in industry—in contrast to the Dutch industrial sector that was so badly hurt when prices went up for the country's North Sea gas exports (and hence the name for the phenomenon itself). Unlike other oil exporters with large rural economies, Indonesia (and Malaysia) undertook a series of macroeconomic policy adjustments designed to protect the rural tradables sector. The large devaluation announced by Indonesia in November 1978 was one of the earliest examples of exchange rate protection to help agriculture, and it was a key factor in the acceleration in agricultural growth between 1978 and 1983.

No short review can do justice to Booth's treatment of the historical antecedents to this growth record or to her skill in placing the Indonesian story in the context of both the internal debate over growth versus distribution and the external comparative literature on the role of agriculture in development. The internal debate has been three-sided, with neoclassical economics, Marxist and radical political economics, and cultural and sociological analysis competing to explain the Indonesian record. The earlier Geertzian view of low potential for growth in the context of shared poverty gave way in the 1970s to the view that capitalist growth mechanisms were spreading rapidly as village safeguards for the poor were eroded. Booth's judgment by the 1980s seems to be that neoclassical mechanisms of wage formation in the context of strong rural-urban links have translated rapid growth into poverty alleviation. Such mechanisms are at the heart of all the success stories in economic development.

Indonesia's emergence, even if tentatively, into this circle of success stories raises substantial hopes for the future. Booth's final chapter spells out the nature of the promise via a comparison of Indonesia's agricultural development since the 1960s with events in Japan during the Meiji era (1868–1912). Booth's argument for the validity of such a comparison is that the underlying historical precursors to modern agricultural growth, including government capacity to develop and disseminate modern agricultural technology, were laid down in the Tokugawa period in Japan but were not in place until the post-colonial era in Indonesia. By juxtaposing the two different historical times with similar historical conditions, Booth is able to show that Indonesia's recent agricultural performance was similar to that of Japan's and that very substantial further gains are possible if Indonesia merely continues to follow the Japanese pattern. Far from running out of opportunities for growth in agriculture, and the associated stimulus to local industry and the overall economy that comes from such growth, Indonesia still has decades of efficient growth in agriculture in prospect. Finding a way to encourage this agricultural growth will be a continuing challenge to Indonesia's policy makers, especially because the commodity focus used historically must give way to a more diversified and balanced

stimulus to rural incomes, but they can take heart that their efforts will be worthwhile. The analytical rationale and empirical evidence to justify these continuing efforts must surely be the two most important contributions of Booth's book.

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Cohen, Ronald, ed. *Satisfying Africa's Food Needs: Food Production and Commercialization in African Agriculture*. Boulder CO: Lynne Rienner Publishers, 1988, 244 pp., price unknown.

This book addresses a very important, albeit complex, problem: How to help solve the food deficit problem facing Africa today. Obviously there is no easy answer, as reflected by the various views expressed in this book. The book serves as a forum in which a variety of social scientists spanning several disciplines (economic anthroplogy, economics, political science and geography) share their reflections on the current African food crisis.

Although not explicit, the book can be split into two general parts. The first part (chaps. 1–4) deal with Africa-wide issues, while the second part (chaps. 5–9) present focused articles on two countries: Kenya and Nigeria. In chapter I, Cohen opens the discussion with an essay on the factors responsible for the current food crisis in Africa and the alternative models for solving this crisis. He does a nice job in scrutinizing earlier colonial and post-colonial approaches, which were urban biased and consequently neglected the rural areas, and the "emancipatory ideas" of the 1960s and 1970s, which encouraged a greater role of the state in allocating resources. According to Cohen, this policy turned out to be a major constraint where it was applied. Cohen then discusses two polar opposite positions which have emerged. The unimodal and multimodal approaches.

The second chapter, by Christopher Delgado, provides an overview of the critical devices necessary for increasing food production in Africa. It stresses the importance of cutting agricultural production costs in order to improve farmers incentives. Delgado also writes that there are needs for (*a*) selecting the type of farmers to whom incentives must be provided, (*b*) setting regional and commodity priorities, and (*c*) concentrating resources along functional lines. Contrary to Cohen's view, Delgado believes that any serious development strategy must be addressed to smallholders, since it is this group that provides the largest share in the supply of food. Therefore, a vigorous smallholder sector will have widespread positive effects on net welfare. Delgado also argues that concentrating resources regionally and along commodity lines has the advantage that it ensures some success somewhere and in any case contributes to the increase in aggregate food supply.

In chapter 3, Goran Hyden asserts that Africa's food crisis is less a matter of the inability of the peasant producers to feed the continent than an institutional and policy problem. Therefore, satisfying Africa's food needs requires a redirection of not only African governments but also the official donor agencies. The reason for this is that development policies are designed with little or no regard for the complexity of development process. For this reason, Hyden concludes that Africa's capability to solve her food crisis depends on the evolution of a new paradigm that opens the door to a new development cycle in which Africa's own resources, whether human or natural, constitute the base for fresh policy action.

In chapter 4, Michael Lofchie uses the case of China's agricultural revolution to offer guidelines for the future recovery of the food crop sector in Africa. He has two concerns: first, there is a need to raise agricultural prices to improve incentives for producers. But Delgado (chap. 2) argues that food prices have risen substantially in Africa over the past few years and that cutting agricultural production costs will be necessary to improve incentives. Second, (like China) Africa's food policy should be guided by the principle of comparative advantage instead of seeking food self-sufficiency at all costs. The foreign exchange constraints are not necessarily alleviated given that cultivation and marketing of food crops in Africa are more import-intensive than the production of export crops for the world market.

Chapter 5 shifts to country studies. In this chapter Robert Bates examines the relationships between drought and famine in Kenya. Key factors identified are the magnitude and spread of the drought; farmers' skill in managing product stores; farmers' technology of food production (e.g., agriculturalist vs. pastoralist); the size of population and the relative rates of growth of population, and agricultural productivity. For example, if population increases at a rate faster than technical change, farming then must spread from areas of high-quality soils and abundant and reliable positive supports to more marginal agricultural regions which are more at risk to climatic fluctuation.

Chapter 6, by Paul Goldsmith, analyzes the productive and commercial success of Miraa, an indigenous tree (cash) crop. The success is due to the market incentives created by a growing salaritariat, the lack of government control and both increased consumption and trade. According to Goldsmith, this success clearly highlights the need to emphasize the dysfunctional role of government-managed agricultural development through parastatals and price controls. My only concern here is that Miraa is not a food product, which perhaps requires a different structure and conduct.

In chapter 7, Angelique Haugerud examines variation across seasons and among households in small farmers' food production levels. Using examples from Kenya, she argues that the "subsistence" nature of small farmers does not imply absence of response to market incentives nor a reflection of uniformly low productive capacity. It is rather a direct response to

market and state institutions as well as uncertainties. An empirical study on Kenya shows that despite several variations in rainfall, some small farm households do consistently produce more food than required to meet their customary consumption needs. This occurred because Kenya farmers' food-crop diversification and subsistence strategies are related to fluctuations in unofficial consumer prices of the food crop; to the unofficial fees charged by the uneven geographic distribution of official food-crop marketing agents; and to the inability of the state marketing board to protect consumers or producers from alternating cycles of gluts and deficits. The major lesson to emerge from this chapter, however, is the highlighting of some of the complexities of small farmers' economic strategies and indication of the importance of understanding local food production patterns.

Chapter 8 is the first of the two chapters that focus on Nigeria. In this chapter Akin Mabogunje does a nice job analyzing the current economic situation in Nigeria. This country is currently undergoing a structural adjustment program (SAP) and the chapter is therefore timely. Despite the strains and stresses of SAP, Mabogunje writes (p. 205), "A new ethos is emerging whose essential indication is a concern with production and individual productivity." Mabogunje notes that there is a trend toward increasing self-employment and enhancing the image of the private sector. But he has one concern: Is Nigeria trying to become a capitalist country with all the insensibility, the lack of human compassion for the weak, and the heavy wastage of human resources that go with this?

The book closes with chapter nine, which also focuses on Nigeria. It is the second contribution of the editor. Cohen argues that food deficit problems in Nigeria have resulted from causes similar to those in many other African countries: low level of technology and very little attention paid to the problem during the colonial era. Cohen argues that, with the mix of development policies followed by successive governments in Nigeria, smallholders alone may not hold the solution to per capita food deficits. It is therefore essential to support a wide variety of projects and programs designed to help rural peoples and to develop commercial food production for the home market under protected conditions.

In general, I like the book because of the varieties of opinions that it contains. Although the papers do not form one piece, the quality of the book is enhanced by this diversity of opinions which cut across several disciplines in social science. I regret that most of the country-focused articles do not give the readers a feel of the range of agricultural policies (successes and failures) currently employed on the continent. Too much emphasis is put on Kenya and Nigeria at the expense of the many other African countries. The articles vary in terms of quality, but this is common to most edited books. More contributions on the Africa-wide issues would have been appreciated. This could have been done perhaps by adding a discussion paper after each contribution. One thing I like about the chapters on Africa-wide issues is that they offer hypotheses which can be tested empirically. There are a few typographical and printing errors, but they do not in any case unduly diminish the quality of the book.

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Dovring, Folke. *Farming for Fuel: The Political Economy of Energy Sources in The United States.* New York: Praeger Publishers, 1988, 152 pp., $37.95.

Although Dovring, as suggested in the subtitle, reviews several U.S. energy options, his book is primarily concerned with providing evidence for his advocacy of a single option. He argues "that the best future mainstay of energy supply in the United States is methanol, eventually to be produced entirely from biomass. This will solve not only the problems of energy supply and vulnerable oil imports but also the farm problems of surplus production, low prices, and soil erosion, and the ecological ones of air pollution and eventual overheating of the atmosphere" (preface).

The author discusses the foregoing proposal as "four problems—one solution" in chapter 1. This is followed by a review of the petroleum age in chapter 2 and a discussion in chapter 3 of the available options for replacing petroleum including liquid fuels from coal and natural gas, oil from shale and tar sands, nuclear power, solar electricity, and biomass. The evidence presented is critical of all the options except methanol from biomass. This is particularly true of the ethanol or gasohol subset of the biomass option, which is presented in chapter 4. Biomass production as a land-use diversification is developed in chapter 5, followed by biomass production as soil conservation in chapter 6. The final four chapters focus on possible supplies and costs of methanol raw materials, converting biomass to methanol, using methanol in vehicles, and some of the political obstacles to adoption of the methanol option.

The evidence presented on the petroleum energy supply and vulnerable oil imports problem is best summarized by the following quote from Dovring: "The Persian Gulf is hardly a place that the United States should trust with half or more of its transportation fuel. Supplies from that area already now carry heavy overheads in military and political costs. If these costs were factored into the price of petroleum (which is not done now) the continued reliance on petroleum as the primary source of transportation fuel would not look as favorable as it is now often made to appear" (p. 14).

The reduced dependence on petroleum would be made possible, according to Dovring, by converting at least 300 million acres of current or potential U.S.

cropland into methanol energy farms. Whereas the ethyl alcohol from grain option is criticized for high energy input and increased soil erosion, the author argues that tree and grass energy farms are more energy efficient and can have the effect of stabilizing soils and reducing the rates at which groundwaters are impaired by fertilizers or pesticides. In addition, fuels from sustainable biomass farms, unlike petroleum, will not add any new carbon to the atmosphere and its waste heat will be no more than the solar heat previously absorbed to build up the biomass.

Fairly detailed information is provided in Dovring's discussion of the possible supplies and costs of methanol raw materials. He concludes that both trees and grasses will produce yields at costs that will be competitive with fossil energy sources within a decade or two. However, the evidence is more mixed regarding the use of methanol in vehicles. While methanol is more efficient, has cleaner emissions, less risk of explosion and fewer environmental hazards from fuel spills than gasoline, it is also more corrosive and toxic, and has problems with cold start, emissions of unburnt methanol and aldehydes, and low visibility of flame when burning.

A major problem with the book is that the author's strong advocacy posture results in a number of subjective statements that take away from an otherwise serious analysis of an important set of problems. Examples include the author's statement regarding deep untapped natural gas reserves that "we should make up our minds never to tap these reserves lest we ruin our planet" (p. 4) or his statement "that the supply of oil will be exhausted can be shown easily" (p. 5). The author also misses other related options including promising evidence on the economics of co-combustion of crop and forest residues with high sulfur coal (Hitzhusen and Abdallah, Gowen and Hitzhusen). In addition, the discussion of soil erosion is weak in its development of externality and downstream cost arguments, and the comparison of net energy versus economic analysis shows little recognition of willingness-to-pay type arguments.

On balance, the book is useful in pointing out the interdependence of several energy, farm policy, and environmental problems. It also develops some evidence for "the methanol from biomass for transport fuel" option but appears to overstate the case. More analysis is needed to estimate the future demand for methanol fuels given the increased concerns with air pollution and global warming. More analysis is also needed on the farm-level and societal (including soil erosion, air pollution, and global warming) economics of tree and grass crops for methanol fuel, particularly on the more erosive acres within the current Conservation Reserve program. The earlier cited work by Gowen and Hitzhusen develops a "plantation forestry for wood gasification" scenario which appears promising in this latter regard.

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Krabbe, J. J. *The Idea of Welfare Economics*. UNIPUB: Wageningse Agricultural University, Wageningen, Netherlands, 1989, x + 73 pp., $85.00

The aim of the essay by J. J. Krabbe is to incorporate the principles of welfare theory into the fields of natural resource and environmental economics. At issue are the functional relationships among natural resource depletion, pollution processes, various forms of technological development and the welfare function.

The static basic model is explicated through a system of production and welfare functions involving land, raw materials, and labor. The model is dualistic in the sense that prices and quantities are endogenous. Environmental technology is considered to be resource sparing. The model is extended to account for the multifunctional uses of land including agricultural production and the preservation of nature. Further, location theory is included in the modeling framework. An important attribute of the model is that unpaid functions, such as "nature" are internalized.

The author notes that the proportion of raw materials used, compared with quantities of land and labor, is rising steadily; depletion of natural resources and environmental pollution are direct consequences. He concludes that present-day technology policy should "cut this fatal tie" (p. 58) through restricting industry, stimulating environmental technology, and modifying the institutional framework relating to production and consumption. Two types of environmental policy are distinguished: complementary policies and interventionist policies. Complementary policies would involve direct government expenditures to ameliorate environmental pollution problems after they occur. Interventionist policies would directly regulate production processes and land uses to minimize or stop the source of environmental pollution.

The model described involves a "whole gamut of substitution elasticities between production and production factors" (p. 57). The author suggests that the possibilities for empirical work to estimate needed elasticities is limited; consequently, no empirical work is offered. Nevertheless the model has heuristic value, according to the author. Even with this caveat, Krabbe enunciates policy prescriptions, e.g., "The institutional alterations must be such that labor is comparatively cheap, in order to minimize the substitution

of raw materials for labor." This presumably will enhance welfare and the environment.

Krabbe is to be commended for his effort to conceptualize the welfare implications of the use of natural resources. The notion that land has multifunctional uses and has spatial qualities is not new. Also the idea that raw materials, land, and labor can substitute and complement each other to produce services and products is not novel. What is new and useful is the link with welfare theory.

The author rightfully acknowledges the lack of empirical work, and he states that the work is incomplete; additional conceptual development is needed. With these admissions, this reviewer feels that the policy prescriptions offered by the author are premature. The assertion that labor must be priced low compared to prices to owners for raw materials in order to promote welfare and the environment needs testing. If the costs of maintaining or enhancing the environment are internalized in the industrial and agricultural production processes, would not the production functions shift and elasticities change? Can we be certain that less raw materials should be used and labor priced comparatively low in order to maximize welfare and environmental values? Also an argument can be made that policies dealing with prices of labor and prices of raw materials relate to questions of equity, to which economics makes only a limited contribution.

The reader must be prepared to digest dozens of equations; however, the content of the work can be ascertained without complete immersion. The translation from the Dutch is somewhat stilted, making interpretation and understanding difficult. Even with the above concerns, this reviewer feels that those interested in natural resource issues will find the essay interesting and useful. It does have heuristic value.

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Leuthold, Raymond M., Joan Junkus, and Jean Cordier. *The Theory and Practice of Futures Markets*. Lexington MA: Lexington Books, 1989, 410 pp., price unknown.

The scope of this book is noteworthy for the effort to integrate the understanding of agricultural futures markets with that of financial futures markets. The book's scope is also noteworthy for the effort to integrate theory and practice, to which end the academic literature is abundantly referenced, and numerous examples are provided for the practitioner. Given the fact that the authors (especially Leuthold) have themselves made numerous contributions to the literature it comes as no surprise that a very useful book results. And given the fact that all three authors are teachers, it follows that they sought to produce, and succeeded in producing, a college-level textbook. Were I still engaged in teaching a course on futures markets, I should not hesitate to adopt this textbook.

This is not to say that I would accept the book as gospel. After all, the professor who does not use his bully pulpit to demonstrate that his knowledge goes beyond that contained in the textbook may incur the dread ego deflation complex. Seeking the road toward understanding of futures markets, I find one convenient juncture at which I would take a different route than they have chosen and be led to a different conclusion as to the primary role of (at least the traditional) futures markets. This occurs at p. 72, where the authors conclude that the portfolio approach, which they credit to Johnson and Stein, "reconciles differences between Keynes' and Working's theories by combining return maximization with risk (minimization)." It is not possible within the confines of a book review to do other than state my position in this matter. Keynes propounded a plausible sounding notion that recognized the need for the harvest surplus to be rationed throughout the year, giving rise to the risk of price decline for those who carried the inventory, thence to the shifting of that risk to speculators on futures markets (Keynes). In support of this simple proposition Keynes hastened headlong into hyperbole, exaggerating the value of the annual cotton inventory by at least an order of magnitude (equating it to the value of all the ships in the world); then fantasizing that the average underestimate of subsequent prices evoked on futures markets ranged between 10% and 20%. But he tried to ward off any empirical estimates of this "risk premium" by saying "the data do not lend themselves to tabulation." In fact the data had already been tabulated and analyzed (U.S. FTC, U.S. ICR) and Keynes had self-destructed on his own petard; but such studies had been little noted, least of all by Keynes.

Working, unlike Keynes, was no Chanticleer. Trusting in painstaking empirical analysis and employing a turgid prose style which eschewed not only hyperbole but any colorful phraseology, he demolished the Keynesian theory without saying so (Working). The great bulk of the hedging on agricultural futures markets was conducted by merchandising firms and processing firms, which prior to the wave of vertical integration after World War II were distinct entities. Working showed that this hedging had to be explained in terms not envisioned by Keynes, and that any risk aversion or risk transfer in the futures markets was incidental.

Back to the alleged reconciliation, there was none to be done, Working having allowed risk its proper place. At least insofar as the traditional (agricultural) futures markets are concerned, portfolio analysis has afforded no insight into their use or performance.

I should never have dwelt so upon the contents of p. 72 of this book, were it not that it reflects an underlying view of the role and purpose of futures trading which permeates the book, and with which I disagree at least as a matter of emphasis. The authors reiterate that the primary role of futures markets is risk management. I would point out that, insofar as the agricultural futures markets are concerned, they have served as the central coordinating mechanisms

of these major economic segments. Whenever government has not usurped this role, prices discovered on futures markets have played it, cash prices having been relegated to the subservient role of "on or off" futures by virtue of the great concentration of the forces of supply and demand in the organized futures markets, which in turn has enabled great reductions in search costs and transactions costs compared with those on any of the satellite markets.

Some ironies are involved here. Keynes, clearly a supporter of futures trading, misconceived and trivialized its role. Opponents of futures trading, whether agrarian populists or dealers in and processors of the commodity, have perceived the role of futures markets correctly but have not liked the results. Agrarian populist opposition has been mostly scapegoating, but at least it has not been gulled into the insurance metaphor. Dealers in onions and potatoes, meatpackers, etc., have had a much more rational basis for their opposition—futures markets erode monopoly power, which they do not like losing. Another irony lies in the fact that the rapid adoption of futures trading in at least some segments has had a great deal to do with risk—but not with the risk of price change addressed by Keynes and his followers. Rather the risk of contract default, so prevalent in private treaty forward contracting, gave rise to a rapid turn to futures trading where default is virtually unknown due to the mark-to-the-market rules. This was really a strong motivation at the Chicago Board of Trade, where first corn and then wheat futures were introduced more than a century ago. Soybean processors were similarly confronted, after World War II, with a "soft contract" problem which was alleviated by futures. Mortgage bankers turned to futures in the mid-1970s in large part because builders and developers were walking away from forward contracts, I dare say that the risk of default contributed more to the growth of traditional futures markets than did the risk of price change.

A third irony rests in the fact that the exchanges themselves, obviously representing their major users, have so willingly espoused the risk transfer raison d'etre. It has served their purposes as an alternative to the image of big traders manipulating price at the expense of producers and consumers—"risk transfer" has an innocent and beneficent ring to it. One successful speculator with whom I had been conversing over coffee, terminated his coffee break by saying to me, in broad jest, that he had to get back onto the floor and sell a little risk insurance to Cargill. They know of course that they are not peddling risk insurance, but they like to have their fun.

A final, somewhat compound irony, may help to explain how I can endorse this book after all the carping I have been doing. Mindful that all of the phenomenal growth in financial futures trading has occurred on the (hitherto) agricultural futures markets, it seems plausible that financial economists would have turned to agricultural economists to gain understanding of the institution in its original environment. That this has not happened may be attributed to a combination of factors; agricultural economists, by and large, have neglected the study of futures markets; exchanges generally purveyed their services to the financial community in terms of risk management; and financial economists, far from neglecting the study, have published more in the past decade than had ever been written before on the subject. They were ready with their portfolio models, their CAP models, and soon-to-be-developed optimal hedge ratios, not only to swamp the academic literature but to swamp the financial institutions with a host of M.B.A.'s. This could mean (I do not say that it does) that risk management is the leitmotif of hedging in the largest and still growing proportion of futures trading.

This book will afford opportunity to teacher and student alike to become familiar with the mechanics of the institution, its history and its regulation. More important, it presents a balanced treatment of issues not fully resolved, as well as a very fair guide to further reading. There is good reason to have a full course devoted to futures markets in an agricultural economics curriculum, good reason to include financial futures in the course, and good reason to choose this as a text.

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Monke, Eric A., and Scott R. Pearson. *The Policy Analysis Matrix for Agricultural Development*. Ithaca NY: Cornell University Press, 1989, xi + 279 pp., $35.00.

This volume uses an organizational and accounting framework, the policy analysis matrix (PAM), to estimate the impact of a variety of government policies on the private profitability of agricultural systems and the efficiency of resource use, as measured by social profitability. The accounting framework which is explicit in PAM attempts to break down the divergence between private and social prices into three categories of effects attributable, respectively, to market failure, distorting policy and efficient policy. This last effect can be thought as countervailing government policies to offset, or partially offset, the negative effects of market failure and distortions.

In addition to a short introduction and concluding

section, the volume consists of three main parts, i.e., (*a*) "Evaluation of Agricultural Policy" (commodity policy, factor policy and macroeconomic policy); (*b*) "Social Valuation in the Policy Analysis Matrix" (social valuation of commodities and factors); and (*c*) "Empirical Estimation of the PAM" (the construction of PAMs for commodity systems; farm-level and postfarm budgets and analysis, the estimation of social profitability, and the interpretation of PAM results).

The reference price which is used for measuring efficiency or comparative advantage (i.e., the social price) for an agricultural commodity is border price, i.e., the world price including transportation costs. The authors claim that the appropriate world prices are "long-run equilibrium levels that approximate best guesses of expected future prices" (p. 29).

The volume contains a painstaking partial equilibrium (Marshallian) analysis of the impact of various types of subsidies and taxes on commodity and factor price distortions. This part is rigorous and useful in illustrating clearly the direct effects of these policy instruments on commodity and factor prices. Chapter 5, which extends the PAM analysis to the impact of macroeconomic (i.e., fiscal, monetary, and budgetary) policy is much less successful for reasons which are mentioned below. A few empirical illustrations of the PAM to specific Portuguese and Indonesian agricultural issues enrich what is otherwise a fairly dry and technical exposition.

The conceptual framework underlying the PAM is mainly an extension of project analysis. It is based on a partial equilibrium approach emphasizing the direct (price) effects of policy instruments rather than the indirect effects. The latter are only captured in a limited way and only to the extent that all shadow prices can be correctly estimated—a most ambitious task. The PAM strength lies in contrast with macroeconomic instruments—on different agricultural commodity systems. Hence, in a limited sense and within agriculture, this approach can be useful in identifying crops enjoying a comparative advantage and the appropriate set of price policies to encourage the production of the most efficient crops.

On the other hand, I have great doubts that the PAM provides a valid analytical and quantitative framework—as its authors seem to claim—when used in a broader sense to explore the impact of macroeconomic policies on efficiency (growth) income distribution and food security objectives. I have three reasons for skepticism. First, the PAM, as such, does not capture the indirect (e.g., intersectoral, interinstitutional) effects of policies within a general equilibrium framework. Models based and calibrated on a social accounting matrix (SAM) are far superior in tracing through the indirect effects of fiscal and monetary policies on growth and income distribution. These indirect effects are often more important than the direct effects. Second, the use of world prices as the main set of reference prices is not without serious risks. If the world agricultural trading system itself is heavily distorted because of agricultural protectionism in the developed countries, using present world prices as reference may only further distort worldwide resource allocation. If, as appears most likely, the EEC will be forced in the near future to reduce its level of support to its farmers, the world prices of many agricultural commodities are bound to go up. The authors are aware of this problem when they say that "observed world prices may be different from those expected in the future" (p. 189). Yet, they argue that "because prediction of the timing, magnitude, and price effects of such policy changes is usually impossible, most estimates of expected prices implicitly assumed constancy of agricultural policies in other countries" (p. 193).

Third, the treatment of the trade-offs among objectives (particularly between efficiency and income distribution) appears totally static in the PAM. For example, the issue is not how government expenditures between current and capital expenditures would be allocated currently to achieve a certain mix of efficiency and poverty alleviation today. Rather, the key issue is what are the consequences of alternative budgetary allocations on efficiency and poverty alleviation now and in the future. Allocating a large share of government expenditures to capital projects may worsen poverty in the short run but because of its positive impact on growth alleviate poverty in the medium run. (Incidentally, the lack of almost any discussion of intertemporal issues and discount rates within the PAM framework is evidence of time-myopia.)

In conclusion, the PAM may provide a valuable framework to identify efficient agricultural systems (and subsectors) within agriculture and help design appropriate price policies. To use it more broadly to explore, for instance, the impact of macroeconomic policy instruments on different development objectives would be to stretch it far beyond its analytical capability.

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Pereira, H. C. *Policy and Practice in the Management of Tropical Watersheds.* London: Belhaven Press, 1989, xvi + 237 pp. Published in the United States by Westview Press, Boulder CO, $27.85.

Land degradation in the third world has become the subject of widespread concern. Erosion, salinization, and related environmental disturbance impinge on the capacity of many developing countries to satisfy expanding demands for agricultural commodities. As is the case farther from the equator, the benefits of water resource development in the tropics are being jeopardized by sedimentation and agricultural nonpoint source pollution.

Among the first to address the problem of watershed management in the tropics was Sir Charles

Pereira. Starting in the late 1940s, he worked for many years in eastern Africa. He has since participated in projects in a number of Asian countries. Distilled into this brief volume are insights gained over four decades of experience.

The author begins by putting watershed management problems of developing countries in perspective. Different forms of land degradation are described, and the costs they impose on society are explained. In addition, natural hazards of erosion, flooding, and the like are acknowledged, the author being careful to describe the "marginal" impacts of human occupation of environmentally fragile lands.

Most of the book addresses technical issues, with special attention given to forestry. The role of tree cover in the management of tropical watersheds with different climatic conditions is outlined. The third world fuelwood crisis is the subject of a separate chapter, as is agroforestry. Recognizing that the farmers and herders who now populate the upper reaches of most third world watersheds will never be fully displaced, Pereira goes on to describe soil conservation measures that can be applied on crop and rangeland in addition to describing less erosive techniques for meeting domestic animals' needs for fodder. Additional chapters are devoted to drainage and salinity issues arising in alluvial lowlands and to flood abatement strategies.

Concise and incisive, these surveys of technical issues are of enormous practical value to economists and other social scientists called upon to design or to evaluate watershed management initiatives. For example, the twenty-page chapter on the role of forests in watershed management contains highly readable descriptions of how the removal of tree cover affects erosion rates as well as sediment and water yield at lower elevations. Complementing the text is an informative set of photographs, figures, and drawings. Indeed, one of the principal charms of this book is that the author prepared most of the art work himself. He illustrates forest hydrology, for example, with a fine sketch showing trees, subsurface roots, bedrock, and a spring. In addition, one is not likely to forget the extent of an acacia tree's surface roots after seeing another drawing of five men holding a single tree's root network.

The surveys of technical issues in watershed management have one relatively minor shortcoming. No reference is made to literature written after the middle 1980s. As a consequence, one's ability to survey more recent thinking on any particular issue is inhibited. [The early chapters of Gregersen et al. (1987) contain a good survey of more recent literature.] However, Pereira compensates for the omissions of many other authors, who ignore older, often seminal, literature.

A more serious limitation of the book has to do with its lack of policy insights. Taking a Malthusian perspective, the author identifies rapid growth of human and livestock populations as the principal cause of land degradation in the third world. In the final chapter, he calls for national governments and donor agencies to commit more human, financial, and other resources to watershed management. How the latter initiative is supposed to overcome overpopulation is not made clear. In addition, other causes of land degradation, including policies pursued by national governments, are virtually ignored.

Better assessments of government policies, market forces, and other factors contributing to land degradation in the third world are available (Schramm and Warford). But for many of us, from undergraduates to senior social scientists participating in interdisciplinary research on land degradation in the tropics, this book's introductory survey of technical issues is of enormous value.

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Reed, David A. *The Winnowing: Economic Change in Rural America*. Indianapolis IN: Hudson Institute, and University Press of America, 1989, v + 65 pp., paperback, price unknown.

Contextually, Reed's book is ideological. It favors a violent, survival-of-the-fittest, mercantilist, anti-Christian, anti-nationalist technocracy that exploits our own farmers by expecting them to produce more but not make a living doing it and by labeling government efforts to "save the family farm" as "unrealistic" (p. 7).

Reed favors "our [international] competitiveness (p. 64), "free trade in agricultural commodities" (p. 44), and the "inevitable trend" (p. 64) of letting the market "factors" [forces] of "technology and global economic restructuring" "restructure" (p. 44) the "agriculture, manufacturing, and national resource" sectors (p. 64) of rural America. Following Nicholls' argument that America's farm surplus is "too many farmers" (p. 158), Reed opposes public policies to contravene this trend (p. 44), even though its "most obvious effect" "will" be that "far fewer people will be able to make a living as full-time farmers" (p. 5).

He blames the victim by asserting that many farmers are unable "to deal with change when it confronts them" (p. 39), but he did not study their education or the source of their powerlessness. Yet, Reed advocates (pp. 42–45): (*a*) the elimination of income support payments, (*b*) the decoupling of income supports from production, (*c*) the replacement of non-

recourse production loans with market-based alternatives, and (*d*) the use of education vouchers to remove and retrain displaced farmers from rural America.

The policies suggested in the book fail in several ways. First, they divide and destabilize rather than unify American "agriculture": they neglect diversification or other programs (e.g., quality control, product differentiation, direct marketing) to help farmers add and retain value added. Second, they justify serious concerns (e.g., of Galbraith) over the textbook ideology that the market, not the firm or the individual, abuses power (p. 286), or (e.g., of Reich) over subversive collectivized forces of the corporate state, technocracy, and the rationalization of greed over the common good. Third, given the following definitions, they favor a violent, exploitive man. In contrast to an exploitive man, a developmental person values and supports (*a*) pro-developmental economic growth (i.e., a win-win gain in the life chances or quality of life of two or more individuals, groups, sectors, regions, or nations without a loss or sacrifice of the well-being of others); (*b*) rural development, following Cramer and Jensen (p. 450), "all the developmental activities that result in making rural America a better place to live and work"; (*c*) commodity programs which, following Tweeten (cited in Ray and Plaxico, pp. 35–36), promote (*i*) "parity of earning power of farm with nonfarm income," (*ii*) "economic vitality of the farming industry to provide adequate supplies of quality food at reasonable cost for domestic and export needs," (*iii*) "preservation of the environment," and (*iv*) "maintenance of the family farm structure"; and (*d*) peace, the opposite of violence (i.e., anything, including ignorance, insensitivity, or greed, which produces, or refuses to control, forces whose individual or structural effects ignore, harm, or destroy the livelihood or relationships of another).

Space restrictions permit only two examples of the methodological and analytical problems in this book. First, the Hudson Institute asserts (*a*) that "the success of democracies depends not only on economic, military, and scientific prowess, but equally on the moral commitment and values of their peoples" (Daniels, p. 7) and (*b*) its "independent research mission" (Daniels, p. 6). Despite these commitments, Reed's book ignores the morals, values, and economic position of individual farmers, workers, or communities in rural America, accepts the "generous support" (p. iii) of four agribusiness "organizations," and advocates a large volume of low-priced farm commodities. Second, it appropriately notes "the large gap between the economic well-being of rural Americans and their urban counterparts" (p. 1), but it misses the gap's structural source—a lack of competition and the conflict of interest within "agriculture." Following Lappé (pp. 2–3), price-taking farmers buy farm inputs from agribusiness oligopolists and sell (i.e., not market) standardized commodities (i.e., not unique differentiated products or services) to agribusiness oligopsonists.

Its failure to analyze the structure of "agriculture" causes problems throughout the book. For example, when it asserts that "the image of rural America as being dominated by and dependent on agriculture is no longer true" (p. 1) because fewer people "live and work on the farm" (p. 1), it misses the productivity provided to nonfarm sectors by farmers. Following Cramer and Jensen, "the efficiency of American agriculture is second to none" (p. 22) and is "vital to the U.S. economy" (p. 22). In effect, agribusiness and food consumers are dependent on farmers to provide an increased volume (p. 34) of "quality food and fiber at reasonable prices" (p. 22); indeed, "the farm and food system contributes 18 percent of the nation's gross national product" (p. 23). They also note that "advances in agricultural science and technology" (p. 29), "have increased output and lowered agricultural prices"; "as a result some producers have been forced to find other employment" (p. 29). Reed's book favors cheap food over parity by claiming that agriculture has been quick "to reap the large gains in productivity these technologies made possible" (p. 13). It denies the abuse of power and need for public policy observed by Ray and Plaxico (pp. v, x), who realize high farm productivity does not produce high net farm income: (*a*) "Highly *unstable* and chronically *low* farm prices and incomes originate from nature and *market structure*," (*b*) "excess capacity is back with a vengence," and (*c*) they "increasingly require relatively stable farm prices and predictable income." Do we perhaps need a farmer-administered Rural Development Bank to tax the volume and/or value added of the middleman to generate funds for farmers (*a*) to add value by differentiating and marketing their own products at home and abroad; (*b*) to use fewer farm chemicals; (*c*) to conserve and improve the quality of our soil, water, and air; and (*d*) to be less dependent upon costly subsidies?

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Simpson, Donald, and Carol Sissons. *Entrepreneurs in Education: Canada's Response to the International Human Resources Development Challenge*. Ottawa, Ontario, Canada. International Development Research Center, 1989, x + 101 pp., price unknown.

This monograph provides an informed and thoughtful analysis of the historical record and the opportunities and challenges that face Canadian institutions with respect to their involvement in Human Resource Development (HRD) in the third world. It reports on a study sponsored by the International Development Research Center, in Ottawa, in which the professional experiences of the principal author have been supplemented with the results of a focused period of research and a wide-ranging series of interviews and discussions around the issues addressed. The core investigation was initiated in 1984. It did not involve any statistical surveys, and very little related data is presented. Rather, the report summarizes expert opinion with respect to a number of related issues and development in Canada.

The study sees HRD emerging as "the cornerstone" of Canada's aid efforts, and rightly so. This focus, it argues, has supplanted the 1960s emphasis on physical infrastructure development and the "basic needs" emphasis of the 1970s. HRD is broadly defined to include, in addition to traditional formal education; short-term professional training; on-the-job training; supporting food, health, and housing programs; and institution building. The importance of long-run perspective is emphasized.

This shift to a broad definition of HRD is reminiscent of the broadening of the "land reform" movements of the 1950s into the "agrarian reform" perspective of the 1960s, which, of course, while it helped to define that developmental bandwagon more realistically, also undermined the rallying power of simplistic solutions. This study finds a general consensus as to the importance of HRD emerging under the wider definitional umbrella, with less developed countries concluding that their progress depends very substantially on gaining access to western technology and training and with the more developed countries concurring, based on their own experience, that human resource development, broadly defined, is strategic to growth and development and to relevant aid programs. However, it also observes that the question of how to transform this general consensus into effective operational arrangements substantially remains in a state of flux.

One of the more interesting sections is entitled "Market Forces and Profit Making in International HRD." It argues that HRD is a legitimate export industry for economies like Canada in a context in which citizens and organizations in many countries, and especially in those falling in the middle and upper level income range, are actively bidding for the ingredients that they need to import from abroad if they are to transform their HRD initiatives into positive, profitable results. In other words, HRD is recognized to be not just an "aid" issue, but also a "trade" issue. However, the report itself does not specifically address the state of effective demand for the ingredients of HRD on the part of the poorest of the world's nations or the degree to which these nations have been substantially shut out of training opportunities in countries like Canada during the last few decades for want of the needed foreign exchange reserves.

The report recognizes a large potential role for the private sector in international HRD and the need for greater public and private sector cooperation in the process. It gives emphasis to the need for institution building within the public sector of Canada and identifies a number of its existing and potential centers of excellence and cooperative relationships between Canadian institutions and institutions in the less developed countries. New sources of finance are explored, and the need for greater entrepreneurial activity in this respect is emphasized. A small section is devoted to the need to develop better overall databases and networking among institutions within Canada and abroad to support more effective and cooperative programming.

Among the developed countries, in which are concentrated most of the resources and institutions capable of contributing to the HRD development process in the poorer countries, Canada has indeed an impressive record and one of which it deserves to be very proud. Some of its areas of comparative advantage are noted in this study, such as its bilingual capabilities. However, it also recognizes areas in which Canada is at a comparative disadvantage with respect to its major international competitors for HRD support.

The study is quite specifically directed to Canadian readers, and the non-Canadian reader is treated with a surfeit of parochial acronyms without the help of a glossary. The book should help to focus the attention of professionals and organizations in both the private and public sectors of Canada on the strategic issues and developmental possibilities that lie ahead in the HRD area. The study will also be of value to those in other countries who have similar professional interests. Most of these would probably agree that there is a need for comparable studies of existing and potential capacity in all of the advanced countries in order to set the stage for greater and more effective response by all of these countries, if, and when, the current third world debt issue ceases to preclude any major correction of the fundamental inequality in HRD throughout the world upon which so many things depend.

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Tracy, Michael. *Government and Agriculture in Western Europe, 1880–1988*, 3rd ed. New York: New York University Press, 382 pp. $50. Agricultural policy has been a major concern of the European Community (EC) since the inception of the Common Agricultural Policy (CAP). The CAP has been the source of friction with the U.S. and other agricultural exporters and a major issue in the Uruguay Round of negotiations under the General Agreement on Tariffs and Trade. Tracy states, "It must seem surprising that agricultural policy should require so much attention at the highest level. After all, agriculture employs only 8 percent of the labour force and contributes on average only 4 percent of national income in the Community. Yet agriculture has been high on the Community agenda since its outset: it was described initially as the 'pillar' of European integration, but as problems have accumulated, it has appeared increasingly as a major stumbling-block" (p. vii).

The book seeks to explain how European policy arrived at its current state by examining the development of agriculture and government involvement over a long period of time. The study covers a somewhat longer time period and less geography than is implied by the title.

The account focuses on the United Kingdom, France, Germany, and Denmark, with some coverage of the Netherlands and Italy and, very briefly, of some other countries. The four that are treated in detail provide interesting contrasts during the period preceding their involvement in the EC and the CAP. The study provides background needed to appreciate the positions taken by these countries in the development of the CAP.

The book is in three parts plus a conclusion. Part one covers the depression of 1880 to 1910 that is characterized as the first wave of protectionism. Part two treats the second wave of protectionism, the crisis of the 1930s. Part three deals with the period since the Second World War and European integration. The first chapter of each of the first two parts provides an overview of the situation in Europe for the time period involved. Chapters on the United Kingdom, France, Germany, and Denmark follow. Chapters in part one cover the organization of agriculture in the centuries prior to 1880 in addition to the twenty-year period stated in the title.

Tracy's analysis reveals the sharp contrast in reactions to the challenge to European agriculture posed by the shift in comparative advantage in grain production to the New World. "The most advantageous response for European countries was to concentrate on foodstuffs whose production was labor-intensive rather than land-intensive, and for which nearness to the market was an important advantage: in particular, dairy products, meat, fruit and vegetables (these, moreover, were products for which, as a result of rising incomes, the trend of demand was favourable). If agriculture, even when adapted in this way, could no longer provide adequate incomes for the farming population, then the necessary course was to promote a shift of manpower from farming to the growing manufacturing sector" (p. 357). He points out that "in fact, Denmark and the Netherlands were almost the only countries to take positive action along these lines. They reaped an immediate benefit." "Great Britain did nothing, and the result was a forced adaptation, arable farming went into decline and the agricultural population, already small, fell still further" (p. 357). "France, Germany and Italy reacted defensively to the challenge of overseas competition, raising their tariffs on grains in particular, and thereby maintaining or even expanding grain production" (p. 358). The crisis of the 1930s forced all western European countries toward protection, yet the approaches taken in the late 1800s were evident in their positions in the development of the CAP.

The book is primarily a history of the organization of agriculture and the development of governments' roles in it. Despite Tracy's personal involvement as a director in the General Secretariat of the Council of the European Communities and his obvious understanding of the political decision process, he appears to be disappointed that the resulting policies are not more rational. At the end of the book he opines that "public choice" theory more nearly fits the facts than does the "rational choice" paradigm.

This well-documented story of the development of agricultural policy in Europe will be rewarding reading for the serious student of the CAP. It provides the background needed to understand how it came to be as it is. Tracy leaves the reader with an appreciation for the difficulty of change but with little direction for a solution to the current impasse. He finds encouragement in the fact that "it should be remembered that these inefficiencies are those which arise in free-enterprise economies and under parliamentary democracy. The abundance resulting from the dy-

namism of numerous individual farmers is undoubtedly preferable to the shortages which, so far, have characterized centrally-planned agriculture" (p. 363).

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Tweeten, Luther. *Farm Policy Analysis*. Boulder CO: Westview Press, 1989, ix + 399 pp., $48.50.

Farm policy is growing in breadth, depth, and complexity. Anyone unconvinced of that fact need only take up the challenge of reading this volume. It incorporates a massive amount of research and literature on a wide array of traditional and nontraditional issues—farm structure, rural values and beliefs, chronic low returns in farming, macrolinkages, foreign trade, the efficiency of U.S. agribusinesses, and the more current agricultural issues relating to the environment, rural poverty, food safety, and rural development.

Coming from the author that it does, the volume will be widely read, and each reader will make his own assessment. Not all will agree with this review. From the standpoint of a Washington policy maker, however, the volume is a godsend of information on a wealth of problems facing the policy maker and administrator in the agricultural arena. And it fulfills its title: It draws together the results of analyses completed over the past quarter century by a large number of the profession's elite, including Tweeten's. And it interprets these results in a meaningful way.

Readers should be forewarned of one point, however. This volume is not an evening's reading. There is a wealth of information in it, in each chapter. Some of that information requires serious mental gymnastics to fully understand the points being made. The graphs once understood illustrate certain points and will be very useful in classroom environments. But many graphs represent an integration of economic theory and agricultural applications that are fairly complex. As such, they require the reader to have an understanding of both the basic discipline and the agricultural parameters. For the advanced undergraduate and graduate student in agricultural economics, it will prove to be a very useful exposition of research applications in the formulation of agricultural policy.

There are some nonanalytical parts to the volume. One is a "short history of commodity programs" (pp. 323–48) that synthesizes past farm bills. Tweeten observes that "two basic approaches to commercial farm policy are workable: one is to adequately control production and support prices, the other is to leave production uncontrolled and let prices fall to levels that will clear the market" (p. 323). In reviewing the 1950s, he notes that "a Democratic Congress and Republican Secretary of Agriculture Benson concocted an unworkable combination: Price supports with ineffective controls at an inopportune time when the technological revolution had struck full force. The result was unconscionable levels of stocks." The 1960s, he suggests, brought a change in programs that "was expensive to the government, but it did restrain production and reduce the burdensome carryover" (p. 334).

Those years also brought a turning point in farm policy. "The (Kennedy) Administration and the Farm Bureau, which had highly conflicting views on farm policy, chose the 1963 wheat referendum as the battleground for deciding which direction the farm would take" (p. 334). "Over a million farmers and their wives voted, five times the number who had participated in the referendum of the previous year. Only 48 percent voted for the mandatory program. It was a stunning defeat for the Administration" (p. 335). Tweeten adds: "Farmers had made a momentous decision, reversing the trend toward mandatory programs. Advocates of mandatory programs had argued that the public would not stand the high cost of voluntary programs needed to maintain farm income at satisfactory levels. They were wrong—the taxpayer was more tolerant of high Treasury costs than was the farmer of tight controls. And farmers continued to demonstrate their power to obtain favorable legislation even at high cost to taxpayers" (p. 335).

A little later he explains that this support continues despite the declining proportion of farmers in the electorate. "Support has been stronger in Congress than from the executive branch for farm commodity programs. The President mainly has acted to constrain Congress in recent years. To the extent that Congress represents special interests and the President the public interest, that trend will continue" (p. 347).

For those of us interested in program history, the history chapter was interesting reading. For others the technical chapters will be of greater interest. And for readers interested in the structure of agriculture, there is a chapter on family farm prospects. Tweeten notes, "Society may have many reasons to preserve the family farm as discussed in Chapter 3. However, the family farm need not be preserved to maintain farm output and food supplies. Output does not fall as family farmers exit because their operations are mostly taken over by other family farmers who produce more per acre than the operator who left" (p. 32).

Diehard family farm supporters will not welcome this message.

Finally, it seems fair to observe that the volume does not foreclose the opportunity for others to contribute to the literature on farm policy. A few questions are left unanswered. For example, the response of competitor countries to differing price levels is a critical issue in setting U.S. commodity loan rates. This volume refers only obliquely to that issue. It also makes assertions that need more evaluation. "Much raw farm output is produced with greater capital intensity than processed products, hence the U.S. has comparative advantage in the former. These factors help to explain why this nation is not more prominent in supplying high-value processed farm com-

modities in the world market" (p. 194). One wonders if we had as many export subsidy programs for processed commodities as we do for raw farm commodities if this assertion would hold.

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von Witzke, Harald, C. Ford Runge, and Brian Job, eds. *Policy Coordination in World Agriculture*. Kiel, West Germany: Wissenschaftsverlag, Vauk Kiel, 1989, 247 pp., price unknown.

The good news is that the papers in this book are an excellent collection that is focused on world agricultural trade problems and have been edited to a readable form. But, the bad news is that they were prepared before a 1987 symposium in Minneapolis and will be nearly three years old when this review appears.

Compliments should be given to the organizers for getting fine work from the right people, but the acknowledgement to the publishers for "her unique efforts to publish this book quickly" seems to verge on the sarcastic considering the time elapsed. Shortcuts to publishing are too evident: the typed pages are reduced to half their original size; no comments are included, although the program included two respondents to each paper; and a paperback binding has been used that will irritate libraries and relegate it to the pamphlet file or incur the added cost of binding before it enters the stacks.

The nineteen symposium participants (7 from the University of Minnesota) had a broad range of papers to discuss. The volume opens with "Market Integration in Agriculture: An Historical Overview" by Vernon W. Ruttan and proceeds through a variety of presentations to a concluding chapter by Alex F. McCalla, probably the two best-known American writers on agricultural trade and development policy today. But, most of the material was prepared as background for those embarking on the GATT negotiations. It presents excellent history, good empirical analysis, and a number of suggested alternatives for the negotiators to use.

Ruttan's introductory paper sets the stage for discussion of disequilibria in world agricultural commodity markets. He sees little hope for change in the political will that creates trade problems but thinks that economic efficiency, budget constraints, market incentives, leverage, and hegemonic cooperation may overcome some political forces. The ninety references in his paper make a magnificent reading list for a graduate seminar if brought up to date.

Yujiro Hayami's contribution uses his unique knowledge of Japanese agriculture and his work on agricultural development to shed insight on how we got into the current problems, and he constructs "nominal rates of agricultural protection" to compare fifteen countries over the period 1955–84. He outlines a "better alternative" to the interest group battles waged throughout the agricultural policy world but sees no promoter who will stage a new drama.

The obvious promoter would be GATT, and three writers (Runge, von Witzke, and Thompson) use analytical game theory to show what that entity could do if trade were liberalized.

This theme is also covered by Rausser and Wright. After illustrating the global distortions that include Japanese sugar producers, who receive seventeen times the world price, and the Egyptian wheat farmers, who receive more for their straw than for their wheat, they use PSE's (producer subsidy equivalents) to compare country policies. Finding this concept wanting when looking at GATT accomplishments (or lack thereof), they propose producer incentive equivalents (PIES) that incorporate only the components of PSE's that have a net influence on output.

The final three papers are critical of the present agricultural trade structure, and each has proposals for change that could be used by GATT negotiators. Schuh's paper is titled "Redesigning International Institutions and Agricultural Sectors" and moves from the assumption that "a significant share of the world's agricultural output . . . is now produced in the wrong place" through several partial solutions and concludes that we need new international institutions.

Every symposium should have a "devil's advocate," a role played by Robert Paarlberg on the program in this volume. He attacks the basic assumption that world agriculture would benefit from greater international policy coordination and arrives at a conclusion that unilateral liberalization should be pursued, especially in the U.S. sugar and dairy programs.

Winding up the program, Alex McCalla is in his element as the eloquent summarizer. He senses that all the writers agree that "the game has to be taken out of the hands of entrenched agricultural interests but how is the big question." Nations need to "sit down and reason together," but "getting that process started is most vexing."

The process is ongoing in the GATT negotiations. Would that this volume were on every negotiator's reading list. For that purpose, it should have appeared two years earlier—and one more proofreading would have helped, as well.

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Williamson, Jeffrey G., and Vadiraj R. Panchamukhi, eds. *The Balance between Industry and Agriculture in Economic Development*. Proceedings of the Eighth World Congress of the International Economic Association, Delhi, India, vol. 2, Sector Proportions. New York: St. Martin's Press, 1989, xxxii + 427 pp. $59.95.

This volume consists of eighteen papers brought to-

gether under four highly interrelated parts, i.e., (1) sector proportions and economic development: theory and evidence; (2) sector proportions and economic development: country studies; (3) industry versus agriculture in East European economies; and (4) unbalanced productivity advance, agriculture-led development, and rural activities.

The editors provide an excellent introduction to the volume in the form of an overview and review of the major findings and contributions of the papers. This introduction captures the essence of these contributions succinctly and clearly. It not only touches on most of the fundamental questions regarding the relationship between agriculture and other sectors throughout the process of economic development but proceeds also to answer a number of them authoritatively. This reviewer would agree with the editors' own evaluation that the papers make an "enormous contribution . . . and remind us just how far development economics has come . . . since the fifties" (p. xxii). (At the same time, the editors could have been somewhat more modest in their own praise; a number of papers are called, in turn, "excellent," "important," "stimulating," and "marvelous.")

Space limitation precludes more than a selective evaluation of the papers and rich issues covered by them. The volume starts, appropriately, with a paper by Lance Taylor, who provides a comprehensive and rigorous treatment of the anatomy of multisectoral models. The main message is that the extremely large number of alternative specifications of key causal mechanisms affecting supply and demand variables as well as closure rules in such models rules out adopting a "broadly applicable uniform model" (p. 26). Rather, good modelers must have a sense of history and understand the institutions, the structure, and the behavior of the major actors of the socioeconomic system which they tried to capture quantitatively. The very richness of Taylor's paper combined with a concise telegraphic style do not make for easy reading, but the analysis is bound to reward those patient enough to stay with it until the end.

The two papers by Syrquin and Panchamukhi et al., respectively, are excellent prototypes of the "patterns of development" approach. They rely on a database of about 100 nations across three decades since the end of the second World War. Even though a rigid adherence to the structural and intersectoral transformation paths generated by the patterns approach is suspect as a guide to the individual path likely to be followed by any given country in any given period of time, the authors come up with robust findings. Syrquin explicitly recognizes that there is no unique development path; the latter is bound to be influenced by structural characteristics and policies. On the other hand, "the overall nature of the transformation over long periods of time has had a remarkable degree of uniformity" (p. 48).

Among the findings of Panchamukhi et al. is that the thesis that industry is the engine of growth stands discredited when tested against the experiences of developing countries. In fact, "a strong linkage between the growth of the service sector and overall growth in GDP of these countries" (p. 80) is detected.

In an interesting study of the first industrial revolution in Britain, Jeffrey Williamson shows clearly that highly imperfect factors markets greatly constrained Britain from following anything near an optimal industrialization path—a conclusion which is based on the empirical application of a computable general equilibrium model to nineteenth-century Britain.

The final paper in Part I by Hwa shows clearly that "agricultural growth induces productivity increases and, therefore, facilitates overall economic growth" (p. 122). The policy implication which is suggested is that while agriculture is inevitably a "declining industry" from the point of view of its share of both output and employment in the economy, it should not be excessively squeezed to support nonagricultural activities in an early phase of the development process. If anything, an appropriate agricultural development strategy should be formulated so as to accelerate agricultural growth rates. This has by now become conventional wisdom in contrast with the earlier view of the 1950s and early 1960s, which assigned a much more passive and subservient role to agriculture.

Among others, Part II includes three detailed country studies (Korea, Nigeria, and India) of various aspects of the interrelationships between agriculture and other sectors throughout the development process. Leipziger and Petri demonstrate how the agricultural sector in Korea was gradually transformed from a sector facing unfavorable terms of trade to one of benefitting from the type of agricultural protection which is typical of the more industrialized countries.

The common themes which run through the five papers constituting part IV of the volume include (*a*) the link and complementarity between agriculture and industry—a process which is well analyzed for Japan from the late nineteenth century onward by Kaneda; (*b*) the key importance of rural nonfarm activities in contributing employment opportunities to the rural population and making a significant contribution to the alleviation of rural poverty. (This trend is well illustrated on the basis of a number of developing countries by Liedholm and Kilby.); and (*c*) the scope for agricultural development-led industrialization strategy (ADLI). Both Mellor, at the national level, and Irma Adelman et al. at the international level—using a general equilibrium approach—show the benefits which could be derived from an ADLI strategy.

In conclusion, this is an excellent volume—with the exception of part 3 on the experiences of Eastern European economies. It should be read by all serious students of the interrelations between agriculture and the rest of the economy in the development process. For the time being it can claim to be the most definitive and comprehensive treatment available—particularly as other IEA companion volumes come out to

supplement other aspects of the balance between industry and agriculture.

Erik Thorbecke
Cornell University

Zusman, Pinhas. *Individual Behavior and Social Choice in a Cooperative Settlement*. Jerusalem: The Magnes Press, The Hebrew University, 1988. 234 pp., price unknown.

Most of Israel's farm production historically has been the result of collective or cooperative arrangements. The predominant form of those arrangements has been and still is the *moshav*, "a farming community in which all farms are family owned and operated, and all farmers are organized in a village-level, multi-purpose service cooperative—the association" (p. 10). Its preponderance is evidenced by the fact that, as of 1981, the *moshavim* contained 51% of all farm units and 30% of the cultivated land and formed 39% of the gross value added in Israel.

Zusman's book provides an extensive, detailed, and systematic description of the *moshav* as a cooperative settlement-cum-village and an enlightening chronicle of its development, organization, functioning, government, and evolution. It is indeed a treatise on the *moshav*. To reduce its scope to the *moshav*, however, would be highly inappropriate, since the author develops an encompassing conceptual framework capable of handling alternative forms of cooperative organization. What makes this book exceptional is the breadth and depth of the topics and issues addressed and the rigor, both technical and intellectual, of their treatment. From his discussion of collective choice issues, to his treatment of the pricing of credit by the *moshav*, to his insights on behavior in group production, Zusman displays an uncanny keenness of analysis that makes reading this book a delight.

The breakdown of the book provides a complete and well-rounded picture of the *moshav*, featuring discussion of the historical development of the organization (chap. B), rich institutional description (particularly chaps. D, E, and J), and sound and rigorous theoretical analysis of individual behavior in groups and in cooperative settings (chap. C in particular), as well as treatment of the governance structure of the *moshav* (chaps. I and J).

With his insights on the history and workings of the *moshav*, the author displays knowledge usually associated only with insiders. Chapter B creates a well-documented historical record of the legal and economic foundations, as well as the evolution, of the organization. Chapters C and G in particular stand out for their completeness. With its development of the general theory of the *moshav* organization, chapter C provides the theoretical backbone of the book, while chapter G deals with the *moshav* association as a financial intermediary. In these chapters, Zusman has integrated a solid knowledge of strategic behavior in groups and organizations and theories of collective choice and risk management with his analysis of the institutional structure of the *moshav*.

In chapter M, Zusman analyzes the effectiveness of the *moshav* in adapting efficiently to changes in the environment. In the process, he uncovers a number of structural deficiencies in the *moshav* form of organization that tend to lead to over-borrowing and delinquency in loan repayments. This proves to be an interesting and relevant exercise because, shortly after the publication of this book, the potential disaster resulting from such structural problems became evident when the long period of run-away inflation in Israel was brought to a sudden halt in the mid-1980s. As a consequence of their overborrowing, the *moshav* organizations suffered financial collapse, clearly underscoring the seriousness of the problem. As the author points out, these structural deficiencies, coupled with a general weakening of the overall commitment to cooperative values, have put severe stress on the delicate fabric of the *moshav* and have called into question their long-term viability without fundamental structural changes.

Among the book's shortcomings, one could identify first the thin treatment that behavioral strategic dynamics receives. The relevance of a dynamic framework to the subject matter of the book and the policy instruments that a dynamic treatment provides suggest the need for greater coverage in this area. Second, although the author is aware and sympathetic to the fact that "attempts at explaining observed behavioral patterns in the *moshav* often involve appeals to noneconomic cultural factors such as ideology, cooperative ethics, solidarity, kinship relations, etc." (p. 9), he nevertheless minimizes the reliance on noneconomic factors in his analytical framework to explain the economic phenomena of the *moshav*. However, these problems do not overshadow the significant contributions this book makes to our understanding of cooperative settlements in general and to the *moshav* in particular.

Overall, this fascinating book significantly advances our knowledge about a very relevant, yet seldom explored, topic. It transcends the *moshav* in its applicability to many other cooperative modes. Such applications could prove quite useful for the process of development in low income countries, Eastern Europe, and the Soviet Union. Any student of cooperatives, cooperation within institutions, or the socio-economic dynamics of governance will be well-served by a careful reading of this book.

Avishay Braverman
The World Bank

Ph.D. Recipients by Subject, 1989

Agricultural Economics General; Curricula and Teaching; Extension, Profession

David B. Schweikhardt, Michigan State University, "Agricultural Research Funding: Optimal Cost-Sharing Arrangements for State and Federal Investments."

Agricultural Inputs; Capital, Agricultural Finance; Land Appraisal and Prices; Labor; Human Capital

Martha Ainsworth, Yale University, "Economic Theories of Child Fosterage in Côte d'Ivoire."
Celia A. Allard, University of Illinois, "Optimal Participation in the Conservation Reserve Program: Land Enrollment Decisions in a Stochastic, Dynamic Framework."
Kojo Assan, Ohio State University, "Simulation Analysis of Selected Financial Stress Policies and Strategies: The Case of Ohio Agrifax Cash Grain Farms."
Rebecca A. Boldt, University of Wisconsin, "The Effects of Land Titling on Small Farm Production in the Highlands of Ecuador."
Chanyalew Demese, Kansas State University, "Industry Structure in Rural America: The Effect of Change in Industry Structure on Job Loss in the Rural Counties of the North Central Region."
Douglas G. Duncan, Texas A&M University, "Simulating Commercial Bank Performance Under Differing Loan-Deposit Relationships."
Fernando Diz, Cornell University, "Pricing Fixed Rate Mortgages: A New Approach."
Charles B. Dodson, University of Missouri, "Projections of Financial Performance for the Farm Credit System through 1996."
George B. Frisvold, University of California, Berkeley, "Transactions Costs, Labor Contracts and Labor Productivity in Rural South India."
John J. Gruidl, University of Wisconsin, "A Dynamic Analysis of Migration and Employment Change in Selected States of the United States."
Mary E. Hardy, University of California, Berkeley, "An Economic Analysis of Tenure Security in West Africa: The Case of the Senegalese Peanut Basin."
Rosamond L. Naylor, Stanford University, "Rice and the Rural Labor Market in Indonesia."
Maqbool H. Sial, University of Wisconsin, "Impact of Agricultural Credit on Small Farms: Productivity in Punjab-Pakistan."
Mark D. Wenner, University of Wisconsin, "Signaling of Creditworthiness in Rural Credit Markets: An Analysis of Group Lending in Costa Rica."

Agricultural Products; Demand, Supply, Prices; Food, Consumer, and Household Economics

Satheesh Aradhyula, Iowa State University, "Policy Structure, Output Supply and Input for U.S. Crops."
Lapondini Atouga, Texas Technological University, "An Econometric Model of the U.S. Beef-Cattle Industry."
Kenneth R. Bowman, Texas Technological University, "A Multi-Stage Hedonic Market Model of Cotton Characteristics with Separable Supply and Demand."
D. Chadee, University of Manitoba, "Impacts of U.S. Countervailing Duties on the Canadian Hog-Pork Sector: A Policy Simulation Approach."
Cristanna M. Cook, University of Tennessee, "Incorporating Subsistence into Hedonic Price and Nutrient Demand Models."
Bernardo Pacheco de Carvalho, University of Minnesota, "Demand Constraints and Technical Change."
John F. Denison, Louisiana State University, "An Empirical Analysis of the Effects of Quality Factors on the Price of Rough Rice in Louisiana."
Mohsen M. El Batran, Colorado State University, "The Impact of Alternative Policies on the Food Gap for Strategic Crops in Egypt."
Elizabeth Frazao, North Carolina State University, "The Value of Mother's Time and Child Nutrition: A Study in the Bicol Region, the Philippines."
Wan Tran Huang, University of Georgia, "An Econometric Analysis of the Potential for Fresh Vegetables in the Southeastern U.S. with an Application of Optimal Control Theory."
Carlos F. Jaramillo, Stanford University, "Supply Response and Optimal Pricing for a Perennial Crop: The Case of Colombia Coffee."
Safer H. Kahtani, Oklahoma State University, "Complete Food Commodity Demand Systems for Saudi Arabia with Commodity Projections and Policy Applications for Wheat."
Peter K. Karungu, University of Kentucky, "Overshooting of Commodity Prices Relative to Manufactured Prices in a Neo-Keynesian Framework: Application of a Modified Arbitrage Condition."
David S. Kraybill, Virginia Polytechnic Institute and State University, "Regional Adjustments to International Demand Shifts: A General Equilibrium Approach."
Ho-Shui Li, University of Georgia, "Dynamic Analyses of U.S. Ex-vessel Shrimp Prices."
Scott Loveridge, Michigan State University, "Uses of Farm and Market Survey Data to Inform Food Security Policy in Rwanda."
Emily Ann McClain, University of Florida, "A Monte

Carlo Simulation Model of the World Orange Juice Market."

John M. Montgomery, Texas A&M University, "A Quantitative Framework for Economic Analysis of Alternative U.S. Government Policies Affecting the Domestic Raw Peanut Industry."

Benjamin Muse, III, Cornell University, "U.S. Fresh Haddock Markets and Haddock Imports from Canada."

Derrell S. Peel, University of Illinois, "A Dynamic Econometric-Simulation Model of the U.S. Livestock Industry."

Everett B. Peterson, Purdue University, "The Farm-Retail Price Spread Revisited: A General Equilibrium Perspective."

Anderson Reynolds, University of Florida, "An Econometric Analysis of Fresh-Winter Vegetable Consumption: Extensions of the Tobit Model."

Margaret A. Spafford, Cornell University, "Differentials in Determinants of the Nutritional Status of Filipino Children: An Application of the New Household Economics."

Grace Tsai, Iowa State University, "A Dynamic Model of the U.S. Cotton Market with Rational Expectations."

Marilyn D. Whitney, University of Wisconsin, "A Model of Dynamic Equilibrium in the U.S. Wheat Market."

Ann A. Wilkinson, University of Missouri, "The Incorporation of Information in an Almost Ideal Demand System for Food."

Seung R. Yang, Purdue University, "The Distribution of Speculative Price Changes."

Economic Growth and Development; Planning Models, Fluctuations; Technological Change; Aggregate Production Capacity; Regional and Community; Migration

Jeffrey R. Alwang, Cornell University, "The Effect of Commodity Price Policy and Household Structure on Nutritional Status in Côte d'Ivoire."

Kama Berte, Oklahoma State University, "Economic Analysis of Cotton Production in the Northern Côte d'Ivoire."

Patricia B. Boyland, University of California, Davis, "The Effects of Tractorization in Rice Culture in the Philippines."

Garry N. Christensen, Cornell University, "Determinants of Private Investment in Rural Burkina Faso."

Manuel R. Del-Valle, Oklahoma State University, "A Regional Econometric Model for Policy Evaluation: The Agricultural Sector of Oklahoma."

Josue Dione, Michigan State University, "Informing Food Security Policy in Mali: Interactions between Technology, Institutions and Market Reforms."

Margaret V. Douglas, University of Tennessee, "The External Costs to the Carter Community from the Siting of a Municipal Landfill in East Knox County, Tennessee—A Contingent Valuation Analysis."

Curtis M. Dowds, University of California, Berkeley, "Liquidity, Entrepreneurship, Small Enterprise Maturation, and the Development Process: The Case of Furniture Manufacture in Colonia Libertad, Tijuana, Mexico."

Marcel Fafchamps, University of California, Berkeley, "Sequential Decisions Under Uncertainty and Labor Market Failure: A Model of Household Behavior in the African Semi-Arid Tropics."

Keith O. Fuglie, University of Minnesota, "The Adoption of New Agricultural Technology in a Rainfed Rice Farming System in Northeast Thailand."

Lynn R. Harvey, Michigan State University, "A Comparative Analysis of General Fund Revenue, Expenditures and Performance of Michigan County Governments under 500,000 Population 1970–1987."

Timothy W. Kelsey, Michigan State University, "Entitlements and Productivity: Researching the Level and Division of the Fruits of Progress."

James Knudsen, Iowa State University, "School District Consolidation in a Club Goods Framework."

Mamou Kouyate, Purdue University, "A Spatial Equilibrium Analysis of the Rice Sector in the Ivory Coast."

Supachit Manopimoke, University of Hawaii, Manoa, "Choice of Rice Production Technique in Thailand, 1890–1940."

Mesfin Mirotchie, Virginia Polytechnic Institute and State University, "Productivity Analysis of Private and Socialized Agriculture in Ethiopia."

Gary R. Mullins, Oklahoma State University, "Distributional Impacts of Structural Adjustment Reforms on Agriculture in Cameroon."

Abiodun Ojemakinde, Louisiana State University, "Louisiana Agricultural Productivity: A Multi-Input Multi-Output Approach."

Hugo H. Ramos, Michigan State University, "The Financial System Supporting Rice Marketing in Ecuador."

Ali Abdulati Rahuma, University of Alberta, "Productivity Growth and Production Technology in the Prairie Grain Sector."

Hartwig Schafer, North Carolina State University, "Real Exchange Rates and Economic Development. The Case of Sub-Saharan Africa."

Jork Sellschopp, Cornell University, "The Impact of Technical Change on the Spatial Distribution of Agriculture: Bovine Somatotropin and the U.S. Dairy Industry."

Ganesh B. Thapa, Cornell University, "The Impact of New Agricultural Technology on Income Distribution in the Nepalese Tarai."

David L. Tschirley, Michigan State University, "Market Coordination and Supply Management in the Feedgrains/Poultry Subsector of Ecuador."

Pradeep Man Tulachan, Cornell University, "The Potential Contribution of Livestock Sector Development to Farm Income and Employment in the Chitwan Valley of Nepal."

Yassin J. Wehelie, Michigan State University, "The Effects of Policy Adjustments on Food Security in

Somalia: The Case of Maize and Sesame in the Shabelle River Valley."

International Economics; Trade; Integration; Business; Aid

Prasert Chaitip, Mississippi State University, "A Spatial Equilibrium Analysis of the Effects of Trade Liberalization on the Asian and United States Rice Markets."
Woong Je Cho, Pennsylvania State University, "A Dynamic Multi-Output Econometric Model for Assessing U.S.–Canada Free Trade."
Duty D. Greene, University of Minnesota, "The Impact of Economic Policies on the Agricultural Sector and Food Consumption in the Dominican Republic: A Multimarket Analysis."
Rashid Hassan, Iowa State University, "A Temporary General Equilibrium Model with Endogenous Money for Economics Policy Analysis in Sudan."
Huei-Ling Hou, University of Georgia, "Policy Analysis of International Trade in Broilers—A Dynamic Game Approach."
Tsorng-Chyi Huang, Ohio State University, "Monetary Approach to the Competition of U.S. Soybean Exports in the World Market."
Thomas S. Jayne, Michigan State University, "An Analysis of Instability in International Wheat and Rice Markets."
David Karemera, University of Nebraska, "Gravity Models and the Role of Carryover Inventories in International Wheat Trade."
Jin-Ock Kim, Iowa State University, "A Time-Series Analysis of the Real Exchange Rate Movement in Korea."
David S. Kingsbury, Michigan State University, "An Analysis of Price and Non-Price Barriers to Agricultural Marketing and Trade in Southern Africa."
Togar A. Napitupulu, Oklahoma State University, "Structural Adjustment to Exchange Rate Policy in a General Equilibrium Framework: The Case of Indonesia."
John Praveen, University of California, Berkeley, "An Economy-wide Model of Food Policy in India."
Velupillai Premakumar, Iowa State University, "Measuring the Impacts of Credit Restrictions on the Economic Performance of the Debtor Nations."
Khalid Bin Abdul Rahim, University of Illinois, "Trade and Welfare Effects of Unilateral Environmental Regulation: The Case of Malaysian Palm Oil."
Santisuk Sanguanruang, Oregon State University, "An Economic Analysis of the Country Specific Impacts of Freer International Trade in Sugar."
Ghulam Sarwar, University of Nebraska, "Impacts of Changes in Transportation Rate Structures on Exports of Soybeans and Soybean Products from Western U.S. Soybean Production Areas."
Vince E. Showers, Ohio State University, "The Effect of Tariff and Nontariff Trade Barriers on U.S. Wheat."
William M. Snell, University of Kentucky, "Analyzing the Impacts of Government Intervention and Product Differentiation on International Burley Tobacco Trade."
N. B. Sureshchandrababu, Iowa State University, "An Analysis of Demand for Food and Nutrition in India."
Nicolas Van Peteghem, North Carolina State University, "Premia in Forward Foreign Exchange Markets."
Thomas Wahl, Iowa State University, "Modeling Dynamic Adjustment in Japanese Livestock Markets Under Trade Liberalization."
Patrick Westhoff, Iowa State University, The Consequences for Argentina of Alternative U.S. and Argentine Trade and Agricultural Policies."
F. N. Zhong, University of Manitoba, "An Assessment of China's Grain Marketing System: Historical Evolution and Future Direction."

Marketing; Agribusiness; Cooperatives; Transportation; Industrial Organization; Vertical Coordination

Elias T. Ayuk, Texas A&M University, "Optimal Hedging with Options in a Portfolio Context Information and Efficiency."
Francesco S. Braga, University of Guelph, "Hedging Strategies for the Italian Agribusiness Sector."
Malcolm J. Commer, Jr., Mississippi State University, "Analysis of a Least-Cost Production, Processing, and Distribution System for the Southeastern Fed Beef Industry."
Elmo T. Falcon, University of Nebraska, "Discrimination in the Rail Rate Structure for Grain Shipments Before and After the Staggers Act."
John E. Lenz, Washington State University, "A Retail-Level Hedonic Analysis of Milk Component Values."
Stephen W. Martinez, North Carolina State University, "The Optimal Dynamic Hedging Positions for Grain Producers Before Harvest: A Case Study."
Kenneth H. Mathews, Jr., North Carolina State University, "Minimum Risk Hedge Ratios."
James C. McConnon, Jr., Iowa State University, "Methods for Assessing the Likelihood of Country Grain Elevator Failure in the United States."
Sukant K. Misra, Mississippi State University, "Risk Analysis of Cotton Harvesting in the Mississippi Delta."
Kenneth E. Neils, Texas A&M University, "Analysis of Selected Short Hedging Strategies for Texas Wheat and Corn Producers."
Atcharawan Ngarmyarn, Iowa State University, "Testing Futures Market Efficiency: An Empirical Study."
Robert A. Pelly, Ohio State University, "An Investigation of the Pricing of Options on Live Cattle and Feeder Cattle Futures."
Bruce A. Sherrick, Ohio State University, "Option-

Based Assessments of Expected Price Distributions."
Donnie A. Smith, Texas Technological University, "Feasibility for Frozen Vegetable Processing in Northwest Texas."

National Resources; Energy; Conservation; Environment; Wastes; Land Use and Tenure; Recreation; Water; Fisheries

Hisashi Amagai, University of Hawaii, Manoa, "The Optimal Mix of Electricity-Generating Sources for Japan in the Year 2000: A Multiple-Criteria Decision Making Analysis."
John Asafu-Adjaye, University of Alberta, "Issues in the Valuation of Nonmarket Natural Resource Commodities: The Case of Wildlife Resources in Alberta."
Afla O. Ayemou, University of Illinois, "Analysis of Forest Management Strategies in Côte d'Ivoire: An Economic Model."
David W. Briggs, University of Minnesota, "The Optimal Control of Northern Corn Rootworm in Minnesota in the Presence of Dynamic Externalities."
John W. Brown, North Carolina State University, "An Analysis of the Economic Potential of Hybrid Striped Bass Culture."
Ujjayant Chakrovorty, University of Hawaii, Manoa, "Optimal Resource Allocation, Pricing, Investment and a Spatial Externality: The Case of Irrigation."
Jeffrey F. Dale, Oklahoma State University, "Optimal Agricultural Management Decisions for Controlling Nonpoint Sub-Surface Chemical Contamination."
Gerard S. Dharmaratne, Texas A&M University, "Hunting Lease and Characteristics Demand: A Conceptual and Empirical Hedonic Travel Cost Approach."
David W. Griffin, Cornell University, "Future Price Uncertainty and Decisions About Appliance Choice and Fuel Use in the Residential Sector."
John M. Halstead, Virginia Polytechnic Institute and State University, "Managing Ground Water Contamination from Agricultural Nitrates."
Gene R. Heinze Fry, Cornell University, "The Economics of Nuclear Power Plants As They Age: Production (Capacity Factors), Variable Costs, and Retirement."
Kun Hong John, Colorado State University, "Expenditure Function Approach to Empirical Valuation of an Environmental Good: Mosquito Abatement."
Donn M. Johnson, Colorado State University, "Economic Benefits of Alternative Fishery Management Programs."
Hussein Abd El Moniem Ahmed Hebicha, Auburn University, "Catfish Pond Harvesting Efficient Pollution Control and Cost for West Central Alabama."
Scott L. Johnson, Oregon State University, "An Economic Evaluation of On-Farm Strategies for Reduction of Nitrate Groundwater Pollution."
Timothy G. Kelley, University of Illinois, "Evaluating Irrigation System Performance: A Case Study in East Java, Indonesia."
Keith L. Kozloff, University of Minnesota, "Benefits and Costs to Society from Retiring Erodible Cropland: A Case Study of the Conservation Reserve Program."
Padma N. Lal, Unniversity of Hawaii, Manoa, "Conservation or Reclamation: Economic and Ecological Interactions Within Mangrove Ecosystem in Fiji."
Donna J. Lee, University of California, Davis, "Salinity in the Colorado River Basin: A Dynamic Modelling Approch to Policy Analysis."
Jan K. Lewandrowski, North Carolina State University, "A Regional Model of the U.S. Softwood Lumber Industry: Including the Role of Price Expectations, the Role of Finished Product Inventory, and the Impacts of Trade Restrictions on Canadian Softwood Lumber."
Richard J. Lichtkoppler, Auburn University, "The Recreation Opportunity Spectrum and the Recreation Use of Bankhead National Forest."
Luanne Lohr, University of California, Davis, "A Spatial-Intertemporal Analysis of Short-Rotation Forestry as an Agricultural Cropping System in California."
Wirote Manopimoke, University of Hawaii, Manoa, "Transaction Costs and Choice of Petroleum Contract."
Linda L. May, Washington State University, "Economic and Environmental Trade-Offs in Washington Small-Scale Hydropower Evaluation."
Golam Mohammad, Ohio State University, "Estimating Recreation Demand for Lake Erie Charter Fishing."
John N. Nyada, University of Massachusetts, "Bioeconomic Simulation of Alternative Insect Pest Management Strategies in a Multi-Species Setting: A Case Study of Sweet Corn in Massachusetts."
Teofilo Ozuna, Jr., Texas A&M University, "Functional Form Issues and Welfare Measures of Truncated Recreation Demand Models."
Robert S. Pomeroy, Cornell University, "The Economics of Production and Marketing in a Small-Scale Fishery: Matalom, Leyte, Philippines."
Hisham Said El-Osta, University of Nebraska, "Economics of Sediment Control Basins in East Central Nebraska—A Dynamic-Stochastic Simulation Approach."
R. Maria Saleth, University of Illinois, "Rules for Water Allocation in a Small Watershed: A Game Theoretic Approach."
Francis G. Scrimgeour, University of Hawaii, Manoa, "A Conceptual Framework for the Economic Evaluation of Water Harvesting."
Richard B. Standiford, IV, University of California, Davis, "A Bioeconomic Model of California's Hardwood Rangelands."
Jeffrey A. Weber, Washington State University, "Evaluating the Economic Efficiency of Irrigation Development: A State Perspective."

Production Economics and Management; Risk and Uncertainty

R. Dale Ballou, Yale University, "The Impact of the Feed Grain Program on Corn Production."
Ziv Bar-Shira, University of California, Berkeley, "Behavior Under Uncertainty: The Decision Criterion, the Attitude Toward Risk, and the Choice of Labor Supply."
William G. Burghardt, Michigan State University, "An Economic Analysis of Credit Reserve Management by Proprietary Firms Under Uncertainty."
Mario Crisostomo, Kansas State University, "Wheat, Soybean, and Grain Sorghum Rotations Including Double Cropping: An EV Analysis Using Simulated Yields and Prices."
William T. Disney, Auburn University, "Development of Alternative Approaches to Modeling Beef Production."
Godfrey C. Ejimakor, Texas Technological University, "Explicit Incorporation of Farm Program Variables in a Quadratic Risk Programming Model: A Texas South Plains Example."
Israel Finkelshtain, University of California, Berkeley, "Aversion to Income Risk in the Presence of Other Risks: Theory and Applications."
Nona R. French, University of Georgia, "An Investigation into the Formulation of Economically Optimal Rations for Laying Hens."
Alejandro J. Galetto, University of Nebraska, "A Monte Carlo Study of the Effect of Estimation Risk on the Optimal Solutions of Risk Programming Models."
Leon Garoian, III, Texas A&M University, "Optimal Ranch Management Strategies with Stochastic Sequential Decisions Models."
Joyce A. Hall, Purdue University, The Effect of Risk on the Distribution of Benefits from Farm Programs and Land Values."
Syed S. Hussain, University of Illinois, "Analysis of Economic Efficiency: Estimation, Causes and Policy Implications."
Tae-Kyun Kim, Iowa State University, "The Factor Bias of Technical Change and Technology Adoption Under Uncertainty."
Govind P. Koirala, University of Minnesota, "Crop Technology Choice—An Intra-Firm Conceptual and Empirical Model."
John D. Lawrence, University of Missouri, "A Stochastic Dynamic Programming Model for Livestock Producers."
Hong-Il Lim, Texas A&M University, "Structure, Functional Form and Dynamics of Agricultural Production."
James W. Lloyd, Michigan State University, "Decision Support for Livestock Production: Integration of Information Management, Systems Modeling, and Computer Simulation Techniques."
Larry Syu-Jyun Lyu, University of Georgia, "Agricultural Investment and Tobin's "Q" Theory."
Michael A. Mazzocco, University of Illinois, "Valuing Climate Forecasts for Midwestern Agriculture."
William D. McBride, University of Tennessee, "A Bioeconomic Simulation of Forage-Beef Systems Under Risk Conditions."
Yasmin Mustafa, University of Georgia, "An Application of Stochastic Dominance and Optimal Control Theory to Simulated Irrigation Scheduling for Corn in the Coast Plain of Georgia."
Warren E. Myers, Cornell University, "Flexible Returns to Scale and Firm Efficiency: New York Dairy Farms."
Rudolph A. Polson, Texas A&M University, "Multiple Input, Multiple Output Production Choices and Technology in Southern Agriculture: Interstate Comparisons."
Karl Skold, Iowa State University, "The Integration of Alternative Information Systems: An Application to the Hogs and Pigs Report."
Gordon Scott Smith, University of Georgia, "A Stochastic Asset Replacement Model for Regenerate Assets."
Tjeppy D. Soedjana, Oklahoma State University, "Simulation Analysis of a Southern Plains Livestock Ranch Under Uncertainty."
Gerald D. Toland, Jr., Michigan State University, "An Economic Analysis of Alternative Crop Yield Coverage Plans for Multiple Peril Crop Insurance."
Everett Torrence, University of Kentucky, "The Reduction of Farm-Level Risks: The Role of Futures Markets and Diversification."
Russell E. Tronstad, University of Illinois, "Optimal Dynamic Marketing Strategies for Grain Producers: A Case Study of Winter Wheat."
Moenakshi Venkateswaran, Purdue University, "Impact of Weather and Crop Price Information on Grain Marketing Decisions Under Risk and Uncertainty."
Alfons J. Weersink, Cornell University, "The Distributional Impacts of Technical Change on the U.S. Dairy Sector."
Robert D. Yonkers, Texas A&M University, "Impacts of Exogenously Determined Variables on Dairy Farms: A Simulation Modeling Approach."
Katherine D. Young, Texas A&M University, "An Analysis of Texas Cow-Calf Producer Objectives."

Public Issues and Policy; Agricultural Regulations; Taxation; Inflation, Welfare Programs; Poverty; Regional and Community Development; Education; Health

Ramaswami Bharat, University of Minnesota, "Incompleteness in Insurance: An Analysis of Crop Insurance Schemes."
Jay S. Coggins, University of Minnesota, "On the Existence and Optimality of Equilibria in Lobbying Economics."
Elaine M. Jacobsen, University of Florida, "Legislative Behavior and Agricultural Policy."
Janice Krakar, Iowa State University, "Canadian Agriculture Factor Retention Under Different Policy Regimes."

Yong Dae Kwon, University of Hawaii, Manoa, "Political Macro Economy of Agricultural Policy: Rice Policy Adjustments in Korea."
Mary Ann Marchant, University of California, Davis, "Political Economic Analysis of Dairy Policies in the United States."
Bradley J. McDonald, University of Wisconsin, "An Applied General Equilibrium Model of World Agricultural Policy Liberalization."
Steven A. Neff, Stanford University, "The Welfare Implications of Removing U.S. Import Quotas on Sugars and Dairy Products."
Albert J. Reed, North Carolina State University, "Asset Movement in the U.S. Dairy Industry Under Different Policy Regimes."
Charles M. Rendleman, Purdue University, "The Economy-Wide Impact of the U.S. Sugar Program."
David L. Sunding, University of California, Berkeley, "Strategic Participation in Corrective Choice Mechanisms."
Suresh Sureshwaran, Clemson University, "Impacts on Alternative Sectors of the South Carolina Economy of the Flue-Cured Tobacco Price Support Program."
Aysen Tanyeri-Abur, Texas A&M University, "An Agricultural Sector Analysis of U.S. Sugar Policy."

Research Methodology; Modeling; Econometrics; Mathematical Programming; Agricultural Data

Theodore D. Covey, Texas A&M University, "A Time-Series Test for Probabilistic Causality."
Keith R. Criddle, University of California, Davis, "Modeling Dynamic Nonlinear Systems."
Jeffrey Dorfman, University of California, Davis, "Three Essays Involving Time-Series Analysis."

Ph.D. Recipients by Institutions, 1989

University of Alberta

John Asafu-Adjaye
Ali Abdulati Rahuma

Auburn University

William T. Disney
Hussein Abd El Moniem Ahmed Hebicha
Richard J. Lichtkoppler

University of California, Berkeley

Ziv Bar-Shira
Curtis M. Dowds
Marcel Fafchamps
Israel Finkelshtain
George B. Frisvold
Mary E. Hardy
John Praveen
David L. Sunding

University of California, Davis

Patricia B. Boyland
Keith R. Criddle
Jeffrey Dorfman
Donna J. Lee
Luanne Lohr
Mary Ann Marchant
Richard b. Standiford, IV

Clemson University

Suresh Sureshwaran

Colorado State University

Mohsen M. El Batran
Kun Hong John
Donn M. Johnson

Cornell University

Jeffrey R. Alwang
Garry N. Christensen
Fernando Diz
David W. Griffin
Gene R. Heinze Fry
Benjamin Muse, III
Warren E. Myers
Robert S. Pomeroy
Jork Sellschopp
Margaret A. Spafford
Ganesh B. Thapa
Pradeep Man Tulachan
Alfons J. Weersink

University of Florida

Elaine M. Jacobsen
Emily Ann McClain
Anderson Reynolds

University of Georgia

Nona R. French
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Articles

Acreage Decisions Under Risk: The Case of Corn and Soybeans

Jean-Paul Chavas and Matthew T. Holt

An acreage supply response model is developed under expected utility maximization. The resulting framework is used to specify and estimate a system of risk-responsive acreage equations for corn and soybeans in the United States. Particular attention is given to the truncation effects of government price supports on the distribution of corn and soybean prices. Also, a wealth variable is included in the acreage equations. The empirical results indicate that risk and wealth variables play an important role in corn-soybean acreage decisions. The analysis also shows that cross-commodity risk reduction is important in acreage allocation decisions.

Key words: corn-soybean acreage, expected utility maximization, risk, truncation.

Much research has focused on acreage response functions in agriculture. Following the relative success of the Nerlovian approach (e.g., Askari and Cummings), recent developments have attempted to strengthen the link between empirical supply response and economic theory either in a static framework (e.g., Weaver, Shumway, Antle) or in a dynamic framework (e.g., Vasavada and Chambers, Howard and Shumway). At the same time, evidence is increasing that risk and/or risk behavior are important in agricultural production decisions (e.g., Behrman, Just, Lin, Traill). However, the implications of decision theory under risk have played only a minor role in supply response analysis. A wide gap exists between the economic theory of risk behavior and aggregate supply analysis.

The objective of this article is to develop an acreage supply response model under expected utility maximization and to investigate its empirical implications for U.S. corn and soybean acreages. After the presentation of an expected utility model for acreage decisions, testable hypotheses of economic behavior under risk are developed. Multiple sources of revenue uncertainty are modeled, and linkages between government price support programs and the subjective probability distributions of uncertain output prices for decision makers are investigated. This is done by modifying the bounded price variation models considered by Maddala (1983a,b), Shonkwiler and Maddala, and others to include multivariate price distributions. The implications of the theory are then incorporated into the specification and estimation of a system of risk-responsive acreage decision functions for corn and soybeans in the United States, and the results are discussed.

The Model

Consider a farm household producing n crops where A_i is the number of acres devoted to the ith crop and Y_i is the corresponding yield per acre, $i = 1, \ldots, n$. Letting p_i be the market price of the ith crop, then agricultural revenue is given by

$$R = \sum_{i=1}^{n} p_i Y_i A_i.$$

Denoting the cost of production per acre of the ith crop by c_i, then the total cost of agricultural production is

$$C = \sum_{i=1}^{n} c_i A_i.$$

In the present case, revenue (R) is a risky variable because output prices $p = (p_1, \ldots, p_n)$ and

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crop yields $Y = (Y_1, \ldots, Y_n)$ are not observed by the household when production decisions are made. Alternatively, input prices and per acre costs (c_i) are known at the time crop acreages are allocated.

The household then faces the budget constraint

$$I + R - C = qG, \text{ or}$$

$$(1) \qquad I + \sum_{i=1}^{n} p_i Y_i A_i - \sum_{i=1}^{n} c_i A_i = qG,$$

where I denotes exogenous income (or wealth) and G is an index of household consumption of goods purchased with corresponding price index q, qG denoting household consumption expenditures. Equation (1) states that exogenous income (I) plus farm profit ($R - C$) is equal to consumption expenditures (qG).

Let the constraints on acreage decisions be represented by

$$(2) \qquad f(A) = 0,$$

where $A = (A_1, \ldots, A_n)$. Assume that the household preferences are represented by a von Neumann-Morgenstern utility function $U(G)$ satisfying $\partial U/\partial G > 0$. If the household maximizes expected utility under competition, then the decision model is

$$\max_{A,G} EU(G) \text{ s.t. (1) and (2)},$$

where E is the expectation operator over the random variables. After substituting the budget constraint into the utility function, the maximization problem is expressed as

(3)
$$\max_{A} \left\{ EU\left[\frac{I}{q} + \sum_{i=1}^{n} \left(\frac{p_i}{q} Y_i - \frac{c_i}{q}\right) A_i\right]\right\} \text{ s.t. (2), or}$$
$$\max_{A} \left\{ EU\left(w + \sum_{i=1}^{n} \pi_i A_i \right)\right\} \text{ s.t. (2),}$$

where $w = (I/q)$ is normalized initial wealth and $\pi_i = (p_i/q)Y_i - (c_i/q)$ denotes normalized profit per acre of the ith crop, $i = 1, \ldots, n$, and all prices are deflated by the consumer price q.

This formulation illustrates that the acreage decision A is made under both price and production uncertainty. Both yields Y and output prices p are random variables with given subjective probability distributions.[1] Consequently, the expectation E in (3) is over the uncertain variables p and Y and is based on the information available to the household at planting time.

What are the economic implications of the optimization problem (3) for the acreage decision A? Letting A^* denote the optimal acreage choice in (3), such a choice depends on normalized initial income (or wealth) w, expected normalized profits per acre $\bar{\pi}_i = E\{p_i/q)Y_i - (c_i/q)\}$, as well as second and (possibly) higher moments of the distributions of normalized profits per acre π_i, $i = 1, \ldots, n$, denoted here by σ. In other words, the optimal acreage decision can be written as $A^*(w; \bar{\pi}; \sigma)$, where $\bar{\pi} = (\bar{\pi}_1, \ldots, \bar{\pi}_n)'$.

The acreage decision under risk $A^*(.)$ is homogenous of degree zero in (w, p, c, q). While this result does not depend on risk preferences $U(.)$, this well-known homogeneity property involves output price p, input cost c and initial wealth w and the consumer price q. The homogeneity condition implies that acreage decisions can be expressed as functions of the relative prices w/q, p/q and c/q (or their probability distributions). However, unless additional restrictions are imposed on risk preferences (see Pope), it does not imply that the acreage function $A^*(.)$ is homogenous of degree zero in output and input prices (p, c). In other words, the classical result of riskless production theory stating that production decisions depend only on input-output price ratios does not hold in general under uncertainty.

Properties of the Acreage Decision

The empirical implications of expected utility maximization have been investigated by Sandmo, Ishii, Chavas and Pope, Pope, and others. In this section we focus on the theoretical restric-

[1] The formulation in (3) is consistent with a yield function of the form

$$Y_i = \min\{a_i(x_i), b_i(x_i)\}, \; i = 1, \ldots, n,$$

where x_i is a variable input (e.g., fertilizer), and $\min\{a_i(x_i), b_i(x_i)\}$ is assumed to be a concave function of x_i. This is a kinked yield function if $\partial a_i/\partial x_i > \partial b_i/\partial x_i \geq 0$ at the point where $a_i(x_i) = b_i(x_i)$. Moreover, optimum input use $\bar{x}_i$ is not responsive to changing relative prices at the kink (at least within some range of prices). This formulation has been found to provide a reasonable representation of yield functions (e.g., Anderson and Nelson; Ackello-Ogutu, Paris, and Williams). In this context, letting r be the price of the input x_i, the variable cost of production per acre is $c_i = r\bar{x}_i$ in equation (3) (within some range of prices).

tions implied by (3) which can be tested and/or imposed in the empirical specification and estimation of the acreage decision $A^*(.)$.

First, Sandmo and others have examined the relationship between wealth effects, $\partial A^*/\partial w$, and the nature of risk preferences. In particular, a zero wealth effect, $\partial A^*/\partial w = 0$, corresponds to constant absolute risk aversion. Alternatively, $\partial A^*/\partial w \neq 0$ corresponds to nonconstant absolute risk aversion. Nonzero wealth effects are of interest here to the extent that decreasing absolute risk aversion is a maintained hypothesis in much of the economic literature (e.g., Arrow).

Second, the optimization hypothesis (3) implies symmetry restrictions on the slopes $\partial A^*/\partial \bar{\pi}$. These symmetry restrictions take the form

$$\frac{\partial A^c}{\partial \bar{\pi}} = \frac{\partial A^*}{\partial \bar{\pi}} - \frac{\partial A^*}{\partial w} \cdot A^{*\prime}, \tag{4}$$

where A^c is the wealth compensated acreage decision, holding utility constant. The matrix of compensated effects $\partial A^c/\partial \bar{\pi}$ in expression (4) is symmetric, positive semidefinite (Chavas). Expression (4) also indicates that the slope of the uncompensated function $\partial A^*/\partial \bar{\pi}$ can be decomposed as the sum of two terms: the compensated slope (or substitution effect) $\partial A^c/\partial \bar{\pi}$ which maintains a given level of utility plus the wealth effect $(\partial A^*/\partial w \cdot A^{*\prime})$. These results are quite general since equation (4) holds for any risk preferences.

Under constant absolute risk aversion, the wealth effect vanishes implying that $\partial A^c/\partial \bar{\pi} = \partial A^*/\partial \bar{\pi}$. In this case, compensated and uncompensated choice functions have the same slope with respect to $\bar{\pi}$ and $\partial A^*/\partial \bar{\pi}$ is a symmetric, positive semidefinite matrix from (4). This illustrates the influence of risk preferences on acreage choice functions since nonzero wealth effects reflect nonconstant absolute risk aversion. Also, note from (4) that non-negative wealth effects $(\partial A^*/\partial w \geq 0)$ are sufficient conditions to guarantee that an increase in expected returns per acre of the ith crop will result in an increase in the optimal acreage of that crop i.e., $\partial A_i^*/\partial \bar{\pi}_i \geq 0$.

Finally, Chavas and Pope (p. 229) and Pope have derived homogeneity restrictions in the context of the expected utility model (4). In particular, rewriting expression (2) as $f(A) = A_1 - g(A.) = 0$, where $A = (A_1, A.)$, Chavas and Pope have shown that the following restriction holds at the optimum under any risk preferences

$$\frac{\partial A^*}{\partial \bar{\pi}} \left(\frac{\partial f(A)}{\partial A}\right) - \frac{\partial A^*}{\partial w} \cdot \frac{\partial f(A)}{\partial A} \cdot A = 0. \tag{5a}$$

Let the first-order conditions associated with (3) be $E(\partial U/\partial w \cdot \pi) + \lambda \cdot (\partial f/\partial A) = 0$, where λ is the Lagrange multiplier associated with the constraint (2) and $\partial f/\partial A$ is a $(1 \times n)$ of vector. Given $\lambda \neq 0$, substituting these conditions into (5a) yields

$$\frac{\partial A^*}{\partial \bar{\pi}} (\bar{\pi} + \delta) - \frac{\partial A^*}{\partial w} (\bar{\pi}' + \delta')A = 0, \tag{5b}$$

where $\delta = COV(\partial U/\partial w, \pi)/E(\partial U/\partial w)$ is an $(n \times 1)$ vector. Under risk neutrality, $\partial A^*/\partial w = 0$ and $\delta = 0$, implying from (5b) that the acreage decision function A^* is homogenous of degree zero in $\bar{\pi}j$,

$$\sum_{j=1}^{n} \frac{\partial A_i^*}{\partial \bar{\pi}_j} \bar{\pi}_j = 0.$$

This homogeneity restriction of classical production theory states that production decisions are not affected by proportional changes in all input and output prices. However, under risk aversion, $\delta \neq 0$ and (5b) implies that this homogeneity-like restriction takes a different form.[2]

Some empirical implications of specific forms of risk preferences have been presented by Pope. In particular, under constant relative risk aversion, a positive scaling of wealth does not alter optimal decisions (Sandmo).[3] This implies that decisions functions are almost homogenous of degree one in initial wealth, degree one in mean returns $\bar{\pi}$, degree two in moments of order two, and degree s in moments of order s of π. Similarly, under constant partial relative risk aversion, a positive scaling of profit does not alter optimal choices. This implies that decision functions are almost homogenous of degree one in mean returns $\bar{\pi}$, degree two in moments of

[2] Under constant absolute risk aversion, $\partial A^*/\partial w = 0$ and (5b) takes the form $\Sigma_{j=1}^n \partial A_i^*/\partial \bar{\pi}_j(\bar{\pi}_j + \delta_j) = 0$. This illustrates the influence of risk preferences on the restrictions discussed by Chavas and Pope.

[3] The coefficient of relative risk aversion is defined as

$$\tau = \left(w + \sum_{i=1}^{n} \pi_i A_i\right)\kappa,$$

where $\kappa = -(\partial^2 U/\partial w^2)/(\partial U/\partial w)$ is the coefficient of absolute risk aversion. Similarly, the coefficient of constant partial relative risk aversion is

$$\psi = \left(\sum_{i=1}^{n} \pi_i A_i\right)\kappa.$$

order two of π, and degree s in moments of order s of π. (See Pope for details.)

Finally, it is well known that $\partial A^*/\partial\sigma = 0$ and $\partial A^*/\partial w = 0$ under risk neutrality. Alternatively, $\partial A^*/\partial\sigma \neq 0$ and/or $\partial A^*/\partial w \neq 0$ implies a departure from risk neutrality. In particular, under risk aversion, risk will influence the allocation of resources in agriculture.

An Application Under Government Price Support Programs

The acreage decision model (3) involves uncertainty about prices p and yields Y. In this section the influence of government programs on the subjective probability distribution of output prices p is considered by focusing on a price support program which places a floor under the market price. The resulting truncation of the subjective probability distribution of prices will affect expected prices as well as second and higher moments of the price distribution. Thus, a price support program will influence both price expectations and the riskiness of revenue.

Since the effects of multivariate truncation are best understood in the context of a normal distribution (see Johnson and Kotz, Maddala 1983a), we limit our discussion to the normal case.[4] Let $X = (X_1, X_2, \ldots)$ be a vector of normally distributed random variables with mean $\bar{X} = (\bar{X}_1, \bar{X}_2, \ldots) = E(X)$ and variance $V(X) = E(X - \bar{X})'(X - \bar{X}) = \{\sigma_{ij}\}$, where E is the expectation operator. Now, assume that each random variable X_i is truncated from below at a level H_i. Define the truncated random variables

$$x_i = \begin{cases} H_i \text{ if } X_i < H_i \\ X_i \text{ if } X_i \geq H_i \end{cases}, \; i = 1, 2, \ldots.$$

Consider the standardized random variable $e_i = (x_i - \bar{X}_i)/\sigma_{ii}^{1/2}$ and define $h_i = (H_i - \bar{X}_i)/\sigma_{ii}^{1/2}$. The mean and variance of e_i are derived in the appendix. The expected value of e_i is

$$\text{(6a)} \qquad \bar{e}_i = E(e_i) = \phi(h_i) + h_i\Phi(h_i),$$

where $\phi(.)$ and $\Phi(.)$ are the standard normal density function and distribution function, respectively. The second moments of e_i are given by (see appendix)

$$\text{(6b)} \quad M_{ii} = E(e_i^2) = 1 - \Phi(h_i) + h_i\phi(h_i) + h_i^2\Phi(h_i), \text{ and}$$

$$\text{(6c)} \quad M_{ij} = E(e_ie_j) = F(h_i, h_j)\rho_{ij} + [(1 - \rho_{ij}^2)/2\pi]^{1/2}\phi(Z_{ij}) + h_i\phi(h_j)\Phi(k_{ij}) + h_j\phi(h_i)\Phi(k_{ji}) + h_ih_j\Phi(h_i, h_j), \; i \neq j,$$

where $F(h_i, h_j) = \text{prob}(X_i \geq H_i, X_j \geq H_j)$, $\rho_{ij} = \sigma_{ij}/(\sigma_{ii}\sigma_{jj})^{1/2}$, $Z_{ij} = \{(h_i^2 - 2\rho_{ij}h_ih_j + h_j^2)/(1 - \rho_{ij}^2)\}^{1/2}$, $k_{ij} = (h_i - \rho_{ij}h_j)/(1 - \rho_{ij}^2)^{1/2}$, and $\Phi(h_i, h_j) = \text{prob}(X_i < H_i, X_j < H_j)$. It follows that the mean, variance, and covariance of $x = (x_1, x_2, \ldots)$ are

$$\text{(7a)} \qquad \bar{x}_i = E(x_i) = \bar{X}_i + \sigma_{ii}^{1/2}\bar{e}_i$$

$$\text{(7b)} \quad V(x_1) = E(x_i - \bar{x}_i)^2 = \sigma_{ii}(M_{ii} - \bar{e}_i^2), \text{ and}$$

$$\text{(7c)} \quad \text{COV}(x_i, x_j) = E(x_i - \bar{x}_i)(x_j - \bar{x}_j) = (\sigma_{ii}\sigma_{jj})^{1/2}(M_{ij} - \bar{e}_i\bar{e}_j).$$

Expressions (7) provide an analytical evaluation of the truncation effect of a price support program on the mean, variance, and covariance of commodity prices. These results will be used to investigate the influence of government programs on corn and soybean acreage decisions.

Data and Estimation

Assuming that aggregate behavior can be represented by a representative farm household making decisions according to model (3), we propose to specify and estimate the acreage function $A^*(w, \bar{\pi}, \sigma)$ from aggregate data. This is done by analyzing annual time-series data for U.S. corn ($i = 1$) and soybean ($i = 2$) acreage decisions from 1954–85. The acreage variables A_1 and A_2 measure acreage planted to each crop (in millions of acres) and were obtained from various U.S. Department of Agriculture (USDA) publications. The market prices (p_1 and p_2) are average prices received by farmers and were also obtained from USDA publications. The costs of production per acre (c_1 and c_2) were obtained from USDA's cost of production surveys for the 1975–85 period. For years prior to 1975, the cost of production data reported by Gallagher were used. Following Houck et al. and Gallagher, effective diversion payment and support price (p_1^s and p_2^s) variables were used to quantify the price support and acreage set-aside provisions of government programs.[5] The consumer

[4] The normal distribution has also been used widely for modeling truncation effects in a single commodity context. See, e.g., Shonkwiler and Maddala or Holt and Johnson.

[5] Following Gallagher, the effective support prices for corn during the nonprogram years (i.e., no set-aside requirements) 1974–77 and 1980–81 were determined as weighted averages of the loan rate and the target price. The weights in turn are derived from the proportion of total corn acreage planted eligible for target price protection.

price q was measured by the consumer price index as reported by the Bureau of Labor Statistics. Yields per acre were obtained from USDA publications.

To analyze supply behavior under risk, assumptions about the (untruncated) expectations of prices and yields are needed. We use adaptive expectations for the untruncated normalized prices. That is,

$$E_{t-1}\left(\frac{p_{it}}{q_t}\right) = \alpha_i + \frac{p_{i,t-1}}{q_{t-1}}, \tag{8a}$$

where

$$\alpha_i = E\left(\frac{p_{it}}{q_t} - \frac{p_{i,t-1}}{q_{t-1}}\right)$$

as measured by the corresponding sample mean. Similarly, the variance measure used for untruncated normalized prices is

$$\mathrm{var}\left(\frac{P_{it}}{qt}\right) = \sum_{j=1}^{3} \omega_j\left[\frac{p_{i,t-j}}{q_{i,t-j}} - E_{t-j-1}\left(\frac{p_{i,t-j}}{q_{i,t-j}}\right)\right]^2, \tag{8b}$$

where the weights ω_j are .5, .33, and .17.[6] The assumption stated in (8a) that expected prices are a function of the average price of the previous year has been successfully employed in previous research (e.g., Houck et al.; Chavas, Pope, and Kao).

Expression (8b) states that the variance of price is a weighted sum of the squared deviations of past prices from their expected values, with declining weights. These measurements of price risk are also consistent with those used previously in the literature (e.g., Lin; Traill; Brorsen, Chavas, and Grant).

Expressions (8) give the untruncated mean and variance of the price distributions. These results, along with the expressions in (7), determine the mean and variance of the truncated multivariate price distributions associated with price supports p_1^s and p_2^s.

To measure yield expectations, actual yields were regressed on a trend variable. The resulting predictions were taken as expected yields, and the estimated residuals were used to generate the variance of yield and the covariance between price and yield. For simplicity, both the variance of yield and the correlation between price and yield were assumed constant over time.[7]

The farm value of proprietor equity was used as a proxy for initial wealth. Farm equity of corn-soybean producers was obtained by multiplying the U.S. farm value of proprietor equity by the percentage of U.S. farm acreage planted to corn and soybeans.[8]

The acreage equations $A^*(w, \bar{\pi}, \sigma)$ were specified using these data. Consider the first-order Taylor series expansion

$$\begin{aligned} A_{it} = a_i &+ (\partial A_i/\partial w)w_{t-1} \\ &+ \sum_{j=1}^{2} (\partial A_i/\partial \bar{\pi}_j)\bar{\pi}_{jt} + \sum_{k\geq j}^{2} \sum_{j=1}^{2} (\partial A_i/\partial \bar{\sigma}_{jk})\bar{\sigma}_{jkt} \\ &+ \Theta_i t + \eta_i D83_t + u_{it},\ i = 1, 2, \end{aligned} \tag{9}$$

where A_{it} is the number of acres planted to the ith crop at time t,

$$\bar{\pi}_{jt} = E_{t-1}\{(p_{jt}/q_t)Y_{jt} - (c_{jt}/q_t)|p_t \geq p_t^s\}$$

is the truncated mean return per acre of the jth crop,

$$\bar{\sigma}_{jjt} = \mathrm{var}\,(p_{jt}|p_t \geq p_t^s) \text{ and}$$

$$\bar{\sigma}_{jkt} = \mathrm{cov}(p_{jt}, p_{kt}|p_t \geq p_t^s)$$

are the truncated variances and covariances of output prices, and u_{it} is an error term. A trend variable is included to capture the systematic effects of any omitted variables on acreage decisions over time. Last, a dummy variable $D83_t$ is included to discount the effects of the payment-in-kind program offered in 1983.

Letting $\beta_{ij} = \partial A_i^c/\partial \bar{\pi}_j$ be the compensated slopes with respect to $\bar{\pi}$ and using (4), it follows that equation (9) can be expressed alternatively as

$$\begin{aligned} A_{it} = a_i &+ \alpha_i\left(w_{t-1} + \sum_j A_j\bar{\pi}_{jt}\right) \\ &+ \sum_j \beta_{ij}\bar{\pi}_{jt} + \sum_{k\geq j} \sum_j \gamma_{ijk}\bar{\sigma}_{jkt} + \Theta_i t \\ &+ \eta_i D83_t + u_{it},\ i = 1, 2, \end{aligned} \tag{10}$$

[6] Several weighting schemes were used to gauge the sensitivity of the results obtained to the specification of the ω_j coefficients. The alternative weights used were (.8, .15, .05), (.7, .2, .1), (.5, .3, .2), and (.33, .33, .33). In all instances, the results compared favorably with those obtained using (.5, .33, .17) in terms of signs, significance of coefficients, and model fit. In addition, the conclusions regarding symmetry, wealth effects, and the nature of risk preferences were unaffected by the weighting scheme.

[7] The (untruncated) correlation between price and yield was estimated to be .320 for corn and .279 for soybeans. The (untruncated) correlation ρ between p_1 and p_2 was also assumed to be constant for all years. The estimated value was $\rho = .753$.

[8] Initial wealth was also constructed by multiplying U.S. farm equity by the proportion of net income from corn and soybean production to total net cash farm income. The results obtained using this alternative wealth measure were comparable to those obtained using acreage-weighted wealth. This result is encouraging since the wealth variable is only a proxy for the true equity positions of corn and soybean producers.

where $\alpha_i = \partial A_i/\partial w$ and $\gamma_{ijk} = \partial A_i/\partial \bar{\sigma}_{jk}$. In the absence of a priori information about functional form, equation (10) provides a local approximation to the decision function $A^*(.)$. Also, the symmetry of (4) implies that $\beta_{ij} = \beta_{ji}$, $i \neq j$. Thus, equation (10) is convenient for testing and/or imposing the symmetry restrictions (4).

Equation (10) can be used directly for an empirical analysis of acreage decisions for soybeans. The corn acreage equation ($i = 1$) is specified according to (10) except that corn diversion payments (*DP*) are also included as an intercept shifter. The model parameters are estimated by seemingly unrelated regression.

Results and Implications

The econometric model (10) is used to test various hypotheses about economic behavior under risk. The first hypothesis examined is the symmetry restriction (4) implied by expected utility maximization. This test is general since the symmetry restriction holds for any risk preferences. The null hypothesis associated with (4) is H_o: $\beta_{12} = \beta_{21}$, and the F-value for the test was $F(1, 45) = 0.002$. Thus, the symmetry restriction cannot be rejected at any usual levels of significance. The implication is that acreage decisions, as represented by equation (10), are consistent with the symmetry restriction implied by expected utility maximization.

With the symmetry restrictions imposed, the parameter estimates of equations (10) are reported in table 1, along with several key measures of model fit and performance. The estimated model explains historical variations in corn and soybean acreages well as indicated by the high R-squares. Serial correlation is also apparently not a problem as reflected by the single-equation Durbin-Watson statistics. Many of the parameter estimates are large relative to their standard errors and have signs consistent with the theory.

The compensated own-revenue elasticities are .068 and .279 for corn and soybean acreage, respectively (table 1). Alternatively, the compensated own-price elasticities for corn and soybeans are .158 and .441, respectively.[9] These mean-response elasticities appear reasonable and compare favorably with those reported elsewhere (e.g., Gallagher; Lee and Helmberger; Tegene, Huffman, and Miranowski). The risk elasticities are generally small, although soybean acreage appears more risk responsive than corn acreage. This result is not surprising because government intervention has been less important in the soybean market than in the corn market. Finally, the elasticities with respect to initial wealth are .087 and .270, for corn and soybean acreage, respectively.

Having found evidence in favor of the expected utility model (3), the next step is to test for the nature of risk preferences taking the symmetry restriction $\beta_{12} = \beta_{21}$ in (10) as maintained. The hypothesis of risk neutrality is treated as H_o: $\gamma_{ijk} = 0$ and $\alpha_i = 0$ for all i, j, k. The F-value for this test was $F(8, 46) = 7.367$, which implies that the null hypothesis can be rejected at the 5% level.

Table 1. Estimated Corn and Soybean Acreage Equations with Symmetry Imposed, 1954–85

	Corn Equation	Soybean Equation
Intercept	80.981**[a]	1.978*
	(1.543)	(1.579)
Corn diversion payments (\$/acre)	−66.347**	
	(3.865)	
	[−0.075]	
$\bar{\pi}_1$ (\$/acre)	0.116**	−0.166**
	(0.046)	(0.043)
	[0.068]	[−0.164]
$\bar{\pi}_2$(\$/acre)	−0.166**	0.255**
	(0.043)	(0.064)
	[−0.107]	[0.279]
$\bar{\sigma}_{11}$	33.583	−75.834*
	(39.285)	(43.886)
	[0.020]	[−0.077]
$\bar{\sigma}_{22}$	15.157**	−16.021**
	(6.677)	(7.472)
	[0.049]	[−0.087]
$\bar{\sigma}_{12}$	−74.420	92.282*
	(45.049)	(49.796)
	[−0.070]	[0.147]
$w + \Sigma_j A_j \bar{\pi}_j$	0.066**	0.122**
	(0.023)	(0.025)
	[0.087]	[0.270]
t	−0.242**	1.534**
	(0.109)	(0.106)
$D83$	−14.545**	−1.880
	(2.045)	(2.049)
R^2	0.941	0.989
Durbin-Watson	1.695	1.875

[a] Standard errors are in parentheses below the parameter estimates. Elasticities evaluated at the sample means are presented in brackets. A double (single) asterisk indicates significantly different from zero at the 5% (10%) significance level.

[9] The uncompensated own-revenue elasticities for corn and soybean acreage are .071 and .285, respectively. Similarly, the uncompensated own-price elasticities are .166 and .450, respectively, for corn and soybean acreage.

The hypothesis of constant absolute risk aversion can be tested as H_o: $\alpha_1 = \alpha_2 = 0$. The F-value for this test was $F(2, 46) = 17.589$, indicating a rejection of the null hypothesis at the 5% level. This result provides evidence that the risk preferences of corn and soybean growers are not characterized by constant absolute risk aversion over the period of analysis.

The empirical results presented in table 1 also show positive wealth effects $\partial A^*/\partial w > 0$. In the single-product case, Sandmo has shown that a positive wealth effect in supply response implies decreasing absolute risk aversion (DARA). To the extent that Samdmo's result holds in the multiproduct case, our analysis indicates that farmers are decreasingly absolute risk averse.[10] While it is well accepted that agricultural producers may exhibit DARA, this appears to be the first empirical illustration of positive (and significant) wealth effects in an aggregate agricultural supply model.

From equation (4), having wealth elasticities $\partial \ln A^*/\partial \ln w$ that are different from zero or one implies that the uncompensated slope matrix $\partial A^*/\partial \bar{\pi}$ is not symmetric.[11] Yet, the symmetry of uncompensated price slopes has been imposed as a maintained hypothesis in many previous studies of aggregate supply response (e.g., Shumway, Antle). Our analysis indicates that the implications of riskless production theory may not apply to supply response analysis under risk.

Finding evidence against the hypothesis of constant absolute risk aversion also raises questions about the appropriateness of mean-variance risk analysis. Indeed, the mean-variance approach is typically motivated under constant absolute risk aversion and normality, which imply zero wealth effects. Our results suggest a need to incorporate a wealth variable in programming models of risk.

The existence of wealth effects may also have policy implications. If corn-soybean farmers exhibit DARA, then higher private wealth tends to offset their need for income and price protection. Hence, the existence of positive wealth effects could provide a possible justification for income transfers to corn-soybean farmers with low initial wealth.

In order to obtain additional insights into the nature of risk preferences, the tests proposed by Pope were performed at the mean values of the sample data. Testing the hypothesis of constant relative risk aversion (CRRA) consists of testing whether a rescaling of terminal wealth has a zero effect on acreage decisions. The F-value for the CRRA hypothesis was $F(2, 46) = 28.429$. Also, testing the hypothesis of constant partial relative risk aversion (CPRRA) considers whether a rescaling of profit has a zero effect on acreage decisions. The F-value for the CPRRA hypothesis was $F(2, 46) = 9.126$. Using normal significance levels, these results indicate that neither CRRA nor CPRRA characterize the risk preferences of corn-soybean producers. In short, many of the simple utility function representations are not supported by the data.[12]

Finally, the supply models were simulated at alternative support price levels. Because of the truncation effects, changing the support price levels will influence the means, variances and covariances of producer prices [see eq. (7)]. Selected static simulation results for the effects of support prices on expected prices, price risk, and acres planted are reported in table 2. As expected, increasing the support price of a crop tends to expand its acreage, although the relationship is nonlinear. For example, when the support price is much below the expected market price, the truncation effect is negligible and the price support program has only a limited impact on acreage decisions. Alternatively, as support price levels, the truncation effects become larger, and the resulting impact on acreage decisions is more pronounced.

The cross-commodity price effects reported in table 2 are of interest since increasing the support price for a commodity tends to increase its expected price and thus decrease the acreage of the substitute commodity. However, the risk-reducing effect of a price support program also influences acreage substitution. The net effect of the soybean support price on corn acreage is negative (table 2). However, the net effect of the support price for corn on soybean acreage is positive for low price support levels (e.g., effective support prices less than $1/bu), and negative otherwise (see table 2). Thus, within some price range the risk-reducing effect of corn support prices on soybean acreage is positive and

[10] This is also consistent with much of the economic literature (e.g. Arrow, Binswanger).

[11] The null hypothesis that the wealth elasticities equal one was also tested. It was rejected at usual significance levels.

[12] The acreage elasticities with respect to a proportional increase (rescaling) of terminal wealth were −.025 for corn and .368 for soybeans when evaluated at the sample means. Similarly, the acreage elasticities with respect to a proportional increase (rescaling) of profit were −.117 for corn and .082 for soybeans. While the test results indicate that corn and soybean producers do not exhibit CRRA or CPRRA, it is not clear whether relative risk aversion or partial relative risk aversion is increasing or decreasing.

Table 2. Simulation of the Effects of Support Prices for Corn and Soybeans

Support Price of Corn ($/bu)	.2	.4	.6	.8	1.0	1.2	1.4	1.6	1.8
Expected corn price	1.30	1.30	1.30	1.30	1.31	1.35	1.45	1.61	1.80
Variance of corn price	.055	.055	.055	.054	.046	.029	.011	.002	.0002
Covariance corn/ soybean prices	.085	.085	.085	.084	.078	.059	.030	.009	.002
Corn acres	74.119	74.119	74.120	74.147	74.426	75.611	78.021	80.734	82.959
Soybean acres	44.655	44.656	44.659	44.673	44.566	43.624	41.088	37.741	34.716
Support Price of Soybeans ($/bu)	**.4**	**.8**	**1.2**	**1.6**	**2.0**	**2.4**	**2.8**	**3.2**	**3.6**
Expected soybean price	2.90	2.90	2.90	2.90	2.91	2.95	3.07	3.30	3.62
Variance of soybean price	.283	.283	.283	.279	.261	.207	.118	.043	.010
Covariance corn/ soybean prices	.085	.085	.085	.084	.082	.072	.051	.026	.009
Corn acres	74.704	74.704	74.701	74.672	74.547	74.278	74.010	73.770	73.127
Soybean acres	44.313	44.314	44.317	44.345	44.460	44.691	44.925	45.309	46.438

Note: Untruncated expected prices are $1.30 for corn and $2.90 for soybeans, while support prices are $1.0 for corn and $2.20 for soybeans. All other variables are set equal to their sample means.

dominates the mean price effect. This result emphasizes the importance of cross-commodity risk effects and the risk-reducing role of price supports.

Conclusions

This study presented a framework for analyzing multiple acreage decisions under uncertainty. A household decision model that includes both output price and yield uncertainty was developed and the resulting behavioral relationships were tested with a system of U.S. corn-soybean acreage equations. The truncation effects of government price supports on the distribution of corn and soybean prices were carefully considered. Expressions relating the truncated means, variances, and covariances for joint normally distributed random variables were developed. Moreover, a wealth variable was included in the estimated acreage equations to facilitate tests of hypotheses about risk attitudes.

The empirical results indicate that both risk and wealth effects are important in corn-soybean acreage allocation decisions. The symmetry restriction implied by expected utility maximization could not be rejected; however, the results also suggest that many commonly used hypothesis about risk attitudes, including CARA, CRRA, and CPRRA, are not supported by the data. These results cast doubt on the use of CARA utility functions. They also suggest that targeting policy benefits toward low income producers may be warranted.

The importance of considering risk in a multicrop framework was illustrated by simulating the acreage models at various price support levels for corn and soybeans. The model simulations illustrate that cross-commodity risk reducton is potentially important since there is some range over which increasing the support price for corn will actually result in more acres planted to soybeans. Such results could not be obtained with a single crop focus.

While the results of this study shed new light on the role of risk in farmers' decisions, further study is required. For example, future research could consider the effects of voluntary participation on acreage response under risk. The analysis could also be expanded to include other sources of risk and a richer set of risk responses than acreage adjustments alone. For example, issues pertaining to financial risk and financial management have become increasingly important in recent years. Finally, the present model could be couched in a rational expectations framework in order to evaluate price support policies in a market equilibrium context.

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Appendix

The Mean of e_i

Let $\phi(.)$ be the standard normal density function. We have

$$E(e_i) = h_i \int_{-\infty}^{h_i} \phi(y)dy + \int_{h_i}^{\infty} y\phi(y)dy$$
$$= h_i\Phi(h_i) + \phi(h_i),$$

where $\Phi(.)$ is the standard normal distribution function.

The Second Moments of e_i

(*a*) M_{ii}.

$$\text{(A1)} \qquad E(e_i^2) = h_i^2 \int_{-\infty}^{h_i} \phi(y)dy + \int_{h_i}^{\infty} y^2\phi(y)dy.$$

But the second term in (A1) can be shown to be equal to $1 - \Phi(h_i) + h_i\phi(h_i)$ (e.g., see Maddala 1983a, p. 365). It follows that

$$E(e_i^2) = h_i^2\Phi(h_i) + 1 - \Phi(h_i) + h_i\phi(h_i).$$

(*b*) M_{ij}, $i \neq j$. Let $\phi(.,.)$ be the bivariate standard normal density function. Then,

(A2)

$$E(e_ie_j) = h_ih_j \int_{-\infty}^{h_j}\int_{-\infty}^{h_i} \phi(y, z)dydz + h_i \int_{h_j}^{\infty}\int_{-\infty}^{h_i} y\phi(y, z)dydz + h_j \int_{-\infty}^{h_j}\int_{h_i}^{\infty} z\phi(y, z)dydz + \int_{h_j}^{\infty}\int_{h_i}^{\infty} zy\phi(y, z)dydz.$$

Note that the second term in (A2) can be written as

$$\text{(A3)} \quad h_i \int_{h_j}^{\infty}\int_{-\infty}^{h_i} y\phi(y, z)dydz = h_i \int_{h_j}^{\infty}\int_{-\infty}^{\infty} y\phi(y, z)dydz - h_i \int_{h_j}^{\infty}\int_{h_i}^{\infty} y\phi(y, z)dydz.$$

The first term on the right-hand side of (A3) is equal to $h_i\phi(h_j)$. From Rosenbaum, and using the notation defined in the text, the second term on the right-hand side of (A3) can be written as

$$-h_i\{\phi(h_j)[1 - \Phi(k_{ij})] + \rho_{ij}\phi(h_i)[1 - \Phi(k_{ji})]\},$$

which implies that

$$h_i \int_{h_j}^{\infty}\int_{-\infty}^{h_i} y\Phi(y, z)dydz = h_i\phi(h_j) - h_i\{\phi(h_j)[1 - \Phi(k_{ij})] + \rho_{ij}\phi(h_i)[1 - \Phi(k_{ji})]\}.$$

By symmetry, the third term on the right-hand side of (A2) is given by

$$h_j \int_{-\infty}^{h_j}\int_{h_i}^{\infty} z\phi(y, z)dydz = h_j\phi(h_i) - h_j\{\phi(h_i)[1 - \Phi(k_{ji})] + \rho_{ij}\phi(h_j)[1 - \Phi(k_{ij})]\}.$$

Likewise, following Rosenbaum, the fourth term on the right-hand side of (A2) can be shown to be

$$h_j \int_{h_j}^{\infty}\int_{h_i}^{\infty} zy\phi(z, y)dzdy = F(h_i, h_j)\rho_{ij} + \rho_{ij}h_i\phi(h_i)[1 - \Phi(k_{ji})] + \rho_{ij}h_j\phi(h_j)[1 - \Phi(k_{ij})] + [(1 - \rho_{ij}^2)/2\pi]^{1/2}\phi(Z_{ij}).$$

After making the appropriate substitutions and collecting terms, (A2) can be shown to be

$$E(e_ie_j) = F(h_i, h_j)\rho_{ij} + [(1 - \rho_{ij}^2)/2\pi]^{1/2}\phi(Z_{ij}) + h_i\phi(h_j)\Phi(k_{ij}) + h_j\phi(h_i)\Phi(k_{ji}) + h_ih_j\Phi(h_i, h_j),$$

where $F(h_i, h_j) = \Phi(h_i, h_j) + 1 - \Phi(h_i) - \Phi(h_j)$.

Designing Expert Systems for Effective Delivery of Extension Programming

Russell L. Gum and Steven C. Blank

Expert systems offer potential as important additions to the current methods used to deliver extension programming to clients. This paper discusses the design of such systems from the viewpoint of learning theory and assesses the cost effectiveness, relative to standard extension programming approaches, of a sample system developed for use with/by cattle ranchers. Results indicate that hybrid expert systems have greater educational impact than traditional programming methods and are more cost effective.

Key words: expert systems, extension, simulation.

The delivery of extension education programs to clients in commercial agriculture is a cornerstone of the extension service charter. Unfortunately, effective delivery of relevant extension programs has become more difficult as (*a*) agriculture has become more technologically advanced; (*b*) relatively homogenous family farms have been replaced by a mixture of large-scale commercial enterprises and smaller part-time farms resulting in a heterogenous mix of clientele, programs, and clientele resources available to solve problems; (*c*) institutional intervention in the form of regulations and government participation in agricultural markets has increased; and (*d*) extension budgets for commercial agriculture programs have decreased in real terms. To counteract the increased difficulty of delivering extension programming to commercial agriculture clientele, new approaches are being sought. For example, computer-based expert systems (hereafter ES), computer driven multimedia programs, and use of electronic media to replace or supplement the traditional one-on-one extension approach are often mentioned as means of improving the effectiveness of extension programming.

This study contributes to the discussion of this issue by evaluating the potential for designing computer-based expert systems as a means of improving the delivery of extension programs to agricultural clients. Of particular concern are extension programs aimed at improving the understanding of managers and providing them with advice on important management decisions. The evaluation process presented here involves application of a teaching program model. The educational impact model developed by Joyce and Showers is used first to guide the design of a sample ES and then as a basis for qualitative evaluation of the contents and expected effectiveness of that ES compared to other extension tools. A summary analysis of costs for the sample system provides a quantitative assessment of the approach's effectiveness.

This paper is organized into five major sections. First, a description of expert systems and a sample application are presented. Next is a brief outline of the educational impact model. Third, training components of the samples ES are evaluated using the educational impact model. This is followed by an analysis of the cost effectiveness of the sample ES compared to other methods used in extension. Finally, conclusions and implications of the study are outlined.

Expert Systems

Many definitions of expert systems can be found in the computer science and artificial intelligence literature. Discussion of two concepts, "function" and "process," are almost always included in those definitions. The standard definitions state that the function of an ES is to "du-

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plicate as nearly as possible the problem solving techniques and rules of the expert" (Hayes, p. 52). The processes used by an ES are usually defined in terms of knowledge representation, inference engines based on symbolic reasoning, and use of heuristics. Waterman (pp. 22, 31) provides the following definitions:

Knowledge representation is "the process of structuring knowledge about a problem in a way that makes a problem easier to solve."

An *inference engine* is "that part of a knowledge-based system that contains the general problem solving knowledge."

Symbolic reasoning is "problem solving based on the application of strategies and heuristics to manipulate symbols standing for problem concepts."

Heuristic is "a rule of thumb or simplification that limits the search for solutions in domains that are difficult and poorly understood."

The most common type of ES is a rule-based system (see Harmon, Maus, and Morrissey for detailed information on building rule-based systems and Rauch-Hinden for a description of commercial applications of such systems). In a rule-based ES, knowledge is represented in terms of rules. For example, a cattle-marketing ES might include a rule stated as "only full truckload lots of cattle can be sold on satellite video auctions." Given a set of rules about cattle marketing and a ranking of marketing alternatives, the inference engine determines the order in which the rules are to be tested. For instance, a strategy termed "backward chaining" could be used to test all rules that are relevant to establish video auctions as the preferred alternative method of selling cattle for a particular rancher. In this example, heuristic knowledge is used to define rules as well as to define the ranking of alternatives. The rules would be tested using a series of questions for the client, and the results would take the form of a recommendation to the client concerning the problem at hand. This ES result is intended to duplicate the recommendation an expert would give clients in that particular situation.

Rule-based systems are extremely useful for certain types of well-defined problems, like diagnosing diseases or trouble-shooting problems with complicated machinery. In general, rule-based expert systems are appropriate under the following conditions: (*a*) The problem is well defined. For example: "My tractor won't start. What is wrong with it?" (*b*) The ES user has confidence in the system's ability to provide correct answers. Such confidence can be acquired if the client is knowledgeable about the subject matter dealt with by the ES and uses the system frequently. Doctors using disease diagnostic programs or mechanics using mechanical trouble-shooting programs are examples of clients who could develop confidence in an ES after frequent use if the knowledge programmed into the system produces correct results.

Unfortunately, many of the questions asked of extension's experts would not satisfy either of the conditions above. Also, the role of extension experts is not simply to solve diagnostic types of problems. Extension experts must spend much of their effort in correctly defining problems for clients. Once problems are defined, extension experts must also spend time educating clients about the problems. Extension programming aimed at problem definition and education would find a rule-based ES of only limited use. Finally, extension experts do spend time solving problems. However, because a large portion of extension clientele do not use extension experts on a regular basis and/or do not have extensive knowledge in technical areas, their confidence in these experts or ES must come from interaction. A computerized ES which just asks a few questions and provides a solution to a problem without significant interaction with the client is not likely to generate the necessary level of confidence in its answers. Therefore, traditional rule-based expert systems which simply ask questions and give advice are not well suited for many types of problems in which extension agents and specialists are involved.

Hybrid Expert Systems

Systems falling under an expanded definition of ES offer potential for use in extension. The role of hybrid expert systems, which incorporate both artificial intelligence and more traditional computer techniques, has been recognized by practitioners in both operations research and artificial intelligence fields. These hybrid systems may be viewed as trying to duplicate the problem-solving techniques and rules of an expert who has access to computer tools such as data bases, statistical analysis, and simulation solftware. Such hybrids have been described as Intelligent Decision Support Systems (Hertz) and Knowledge-Based Management Support Systems (Hayes, p. 53) when their main purpose was to assist managers, and as Intelligent Tutoring Systems (Katz and Schultz or Psotka, Massey, and Mutter) when their main purpose was to provide expert training to students. It is simply a semantic problem

to classify such systems because the real distinctions between these approaches are being challenged, as noted below.

> Operations research (OR) has developed both formal and heuristic solutions to a broad spectrum of real world issues. Artificial intelligence (AI) through its expert systems (ES) approches has recently begun to attack similar problems. I believe that AI/ES or OR applications have similar objectives to permit the executive or decision maker to improve his understanding of, and take desirable actions in a particular domain. Both must build computable models which have equivalent model structure. The surface differences are programming devices that may be stripped away. In the not too distant future, all significant programs intended to provide advice, diagnosis and analysis to aid decision makers will be hybrid. (Hertz, p. 9)

To minimize semantics, this paper uses the generic term "expert system" to describe the sample application presented in the next section. The ES is a hybrid in that it uses a wide mixture of computer techniques as appropriate to accomplish its dual goals of education and problem solving.

System Design

Using this general perspective, an ES was designed to provide extension programming to cattle ranchers. Problems concerning both marketing and production were included to make the test of the sample ES's value as broad as possible. The marketing problems included selecting the type of marketing institution to use in selling cattle and deciding whether to use commodity futures or options markets for hedging. Production problems included the nutritional management of a range cow herd and the associated management of breeding and weaning schedules. The goal of the system is to augment the abilities of ranchers to manage their businesses profitably by providing both the education programs and advice of extension experts in the form of computer software. From extension's viewpoint, the system is designed to provide county extension agents with a tool they can use to give ranchers the equivalent of both a workshop and one-on-one consultation by a team of specialists who are experts in the areas of marketing, range management, and animal science.

The first step was to develop traditional published materials and computer tools necessary for the team of extension experts to present effective workshops and provide useful one-on-one consultation to ranchers. In the marketing area, several extension publications and spreadsheet decision aids were used. To address range nutrition problems, a simulation model relating range conditions to cow performance was developed. A simulation model was chosen as the only practical approach, other than simple rules of thumb, to define the range production process in terms useful to analysis of alternative management decisions by ranchers. A graphics-based simulation modeling program, called Stella™, was used to facilitate development of the simulation by a multidisciplinary team. The basic structure of the model is (*a*) to calculate the nutritional intake of a cow based on the animal and the nutritional value of the forage species consumed; (*b*) to calculate the nutritional requirements of the cow as a function of her weight and stage of pregnancy; (*c*) to calculate the gain or loss in weight of the cow; (*d*) to determine the pregnancy probability of the cow based on her weight at breeding and on her rate of gain in the time period preceding breeding; (*e*) to determine calf weights; and, most important, (*f*) to determine expected economic returns for the lifetime of the cow for a specific management strategy. The model was calculated with daily time steps for a seven-year period in order to determine the present value of a cow under a specific management strategy.

The next step was to design the ES to accomplish the same results as a team of extension experts that present workshops and then work one-on-one with ranchers who had attended the workshops. The design approach had two major components. First, the ES was designed to include all of the learning components described by Joyce and Showers (explained in the next section). Second, HyperCard™ was chosen as a software platform. This allowed the ES to be developed without the necessity of programming in a complex artificial intelligence language such as Lisp or Prolog. It also allowed easy linkages of the ES to the simulation model through a HyperCard™ front end to Stella™, called StellaStack™. In addition, it gave access to a rule-based ES shell programmed as a HyperCard™ application, HyperX™, and the flexibility to link modules programmed in Fortran, Pascal, or C to the HyperCard™ application.

Educational Impact Model

The key to making this package of computer programs a single educational tool which could

achieve the goals of the extension project was using a model of teaching to guide the system's design. The educational impact model of Joyce and Showers (hereafter JS) was used in this effort.

JS state that, when students use what has been learned to solve problems, they are demonstrating that their training has had the highest level of impact possible. Because this is exactly what extension programs need to do, train managers to solve problems, their framework for judging educational impact is appropriate in the context of extension program design and evaluation. JS concluded that the level of impact a teaching program will have is affected by the following training components: (*a*) presentation of theory or description of skill or strategy, (*b*) model or demonstration of skills or models of teaching, (*c*) practice in simulated and classroom settings, (*d*) structured and open-ended feedback, and (*e*) coaching for application.

Further, JS indicate that components (*a*) through (*e*) have increasingly greater levels of impact on students' abilities to solve problems. When all five components are included in a teaching program, up to 75% of students are able to apply what has been learned. The research by JS supports the notion that teaching techniques which incorporate more of the five components will have greater impact than techniques involving fewer training components. This conclusion and the conceptual framework of the five training components are used as a guide to the following description and analysis of the sample ES as an effective extension programming method.

System Design Using the Educational Model

The first training component, presentation of theory is included in the sample ES through an introductory module which includes definitions of terms and concepts, and short courses in alternative cattle-marketing techniques, hedging using futures contracts, hedging using options, range cow nutrition, cow diets, and range forage nutritional values. The specific computer technique used in this module, commonly called hypertext in the computer literature (see Brent or Blank and Gum for more detail on hypertext applications for expert systems), involves presenting text on the screen with bold-faced text being linked to further explanatory sections. For example, in the section introducing video auctions as an alternative livestock-marketing method, reference is made to the concepts of futures and options which are presented as bold-faced words. By selecting the words (moving the cursor over them and clicking with the mouse), the user is presented with the index of a detailed section on hedging which includes both text and working spreadsheets to calculate the results of hypothetical examples. The user can select any of the index items to have the computer display the screens relevant to those topics. If a user selects the option calculator, for example, a working spreadsheet appears which allows the client to calculate the expected results of a hedge using option contracts.

The series of computer screens is displayed in figure 1–3. If a user chooses to obtain the detailed information on hedging and to use the spreadsheets, he or she has at that point been exposed to the theory of hedging (component one of the JS model) and has seen a working example of how to calculate the results of a hedge (component two of JS). Further, the hypertext approach makes effective use of the user's time because the client chooses which material is displayed on the computer screen. If a rancher is not interested in using the futures market to hedge, the computer does not require him or her to page through screens full of that material to get to the information of interest. By using such a free choice system of displaying material, theory can be effectively presented.

The second training component, model or demonstration of skills, is implemented with a walk through of a typical range cow annual production process. This involves a hypertext presentation which includes (*a*) animated computer graphics illustrating the nutritional links to the range cow production processes using the simulation model as a basis, (*b*) a schedule of operations, (*c*) an illustration of hedging using the futures market, and (*d*) a budget for the ranch showing costs and returns.

The third component, practice in a simulated setting, is included as the ES guides ranchers through the process of modifying the computer simulation model to reflect their own ranching situation, and then guides them through the simulation process to evaluate different management alternatives. This is facilitated through the use of an intelligent user friendly front end for the simulation model, called StellaStack, which runs as a HyperCard™ application.

The fourth training component, structured and open-ended feedback, involves a series of evaluation questions the computer system asks the rancher which allows the rancher to comment, discuss, or question the system and/or the re-

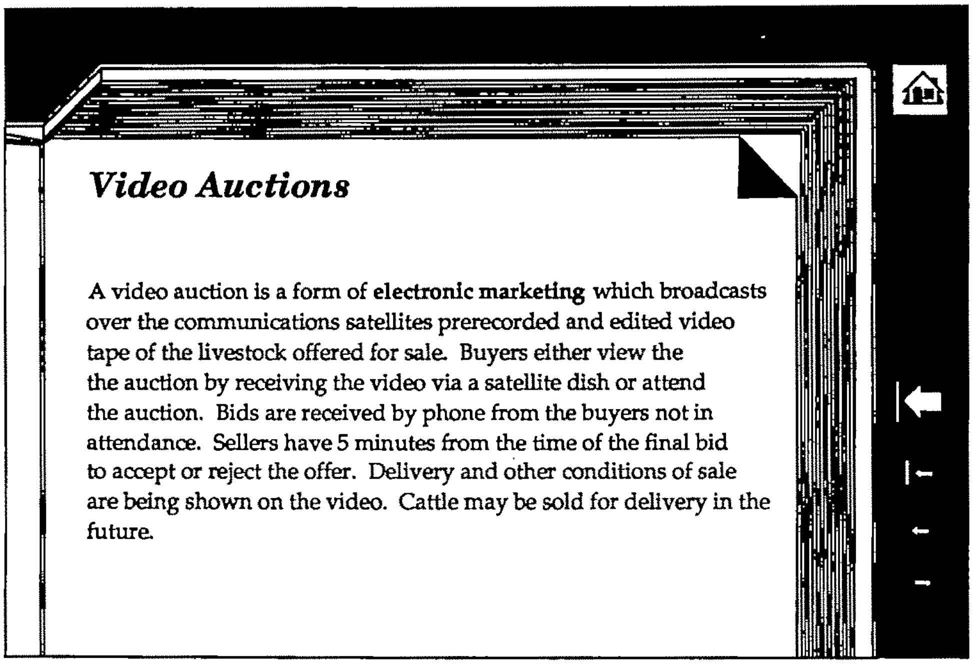

Figure 1. Video auctions

sults generated. This can involve electronic communication with the specialists who designed the system. In addition to setting up a mechanism to provide additional feedback to ranchers, this approach allows the developers of the ES to monitor its use and collect data on its effectiveness. Such information can provide a valuble basis for continuing modification and improvement of the heuristics included in the system.

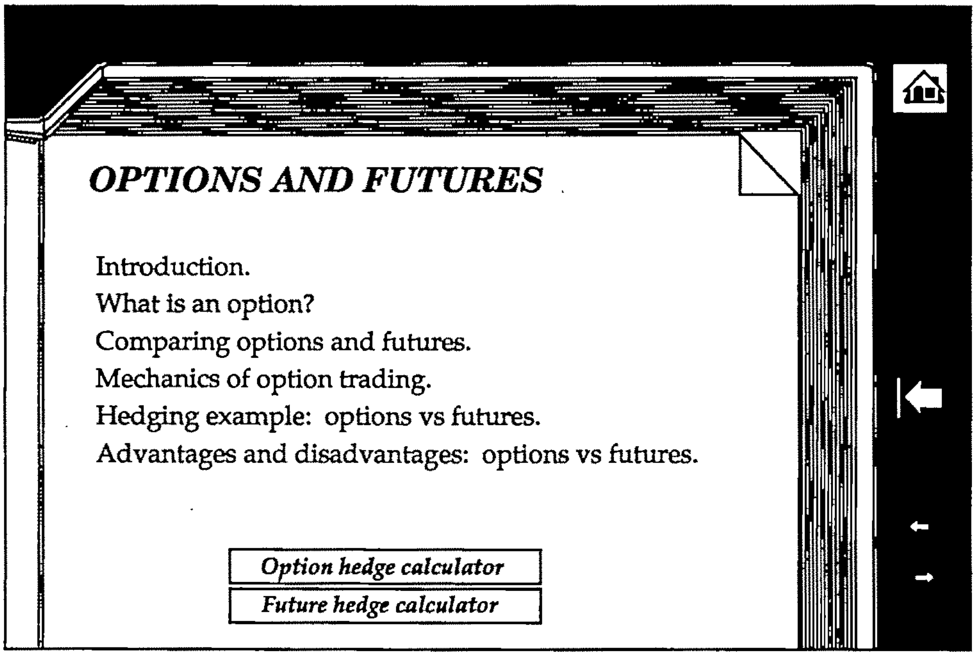

Figure 2. Options and futures

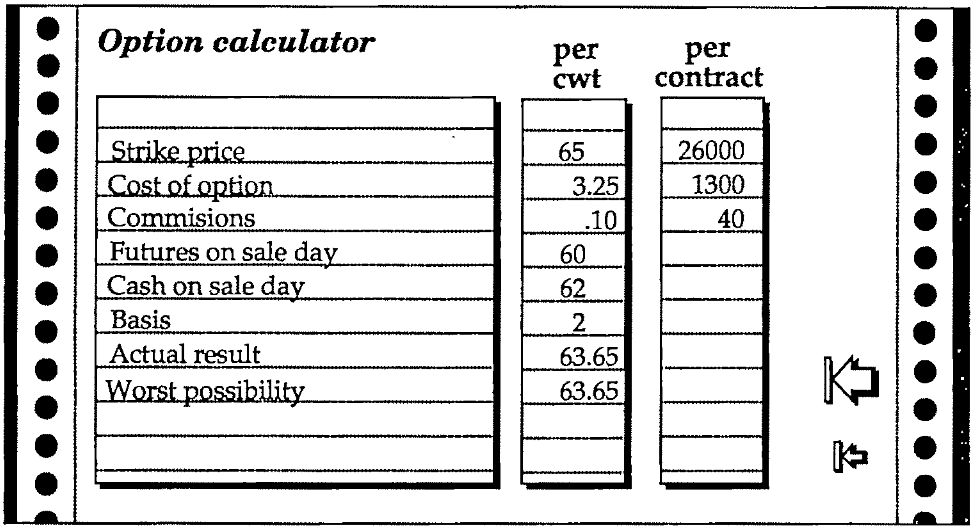

Figure 3. Option calculator

The fifth component, coaching for application, is accomplished by the computer using a rule-based analysis of the simulation results developed by the rancher for a specific management alternative and then suggesting economically reasonable alternatives. For example, if phosphorus is a limiting factor for cow gain under the management alternative being simulated, the coaching module would point this fact out and suggest a reasonable mineral supplementation strategy.

Comparison of Programming Approaches

To provide a base for comparison, the JS model was used to assess other extension programming approaches in terms of their learning components. The results of that qualitative assessment are presented in table 1. The information illustrates that traditional extension outreach techniques can be categorized as those designed for general audiences and which stress presentation of theories, concepts, and general models of the applicability of a potential practice, and those which involve direct contact with a client for the purpose of real-world problem solving. No traditional approach includes more than three training components and only agent/specialist "one-on-one" contact with clientele includes the desirable components of feedback and coaching.

The expanded ES designed as an example is expected to have great impact as a teaching tool because it includes all five learning components, as described earlier. Currently only extension programs designed using a mixture of techniques include all five components. Thus, based on the educational model, the expanded ES approach is expected to be a more effective means of information delivery than any other single programming approach.

Table 1. The Learning Components of Extension Programming Approaches

	Learning Components[a]				
Programming Approach	1	2	3	4	5
General audiences targeted:					
Extension bulletins	X	X			
Spreadsheets			X		
Video tape		X	X		
Interactive video disk	X	X			
Personal contact, small audiences:					
Agent/specialist "one-on-one"				X	X
Agent/specialist workshops	X	X	X		
Traditional expert systems				X	
Expanded expert system	X	X	X	X	X

[a] 1 is presentation of theory; 2, model or demonstration of skills; 3, practice in simulated settings; 4, feedback; 5, coaching for application.

Observations from users of the sample ES have supported this expectation. They have revealed:

(*a*) Cattle producers are significantly more interested in the nutrition module than in the marketing module. This is probably because there are no noncomputerized alternatives which are as effective as the computerized simulation model

in analyzing nutrition management, while noncomputerized alternatives do exist for analysis of marketing decisions. This observation supports the hypothesis that ranchers' analytical abilities are augmented by the simulation model embedded in the ES.

(*b*) The computer is accepted as a valuble tool when a user-friendly interface is in place. Ranchers simply do not have the time or interest to learn how to run a computer. The application of HyperCard™ and the user-friendly animated graphical interface (with numerous on-screen prompts) allows ranchers to overcome their fear of computers and to begin using them as a tool.

(*c*) Ranchers accepted advice from the computer after the ES led them through the simulation and analysis of their nutrition management. This observation is consistent with the hypothesis that the tutorial components of the ES were effective in teaching the principles necessary for nutrition management and that the analytical components provided advice for alternative management strategies that the ranchers viewed as useful.

To provide a quantitative assessment of the sample ES's value relative to other extention programming approaches, a simple cost effectiveness analysis is presented. The costs presented below are derived from the sample system described earlier. The costs represent current estimates for systems configured as outlined. The benefits specified are also best estimates from clients using the sample ES. The costs of the ES are compared to those for an extension program composed of only traditional approaches, yet which is expected to produce similar benefits. That "straw man" program includes both agent/specialist one-on-one and workshop approaches. As shown in table 1, a combination of these two teaching approaches will include all five training components of the JS model, making such a program approximately equal to the ES in expected educational impact. Therefore, the most effective program is that with the lowest cost.

The costs for the range cattle module of the ES are approximately:

Computer hardware	\$4,000 per unit
Computer software	\$600 per unit
Development costs	\$20,000 one time
Maintenance & training costs	\$5,000 per year

Unfortunately, expert systems of the type described here require powerful microcomputers. A reasonable computing platform for the sample system is Macintosh SE 30 with a 40 megabite hard disk and two megabites of memory, a 2,400 baud modem, and a printer. The ES requires HyperCard™ (the all-purpose computer program construction set which is used as a shell to put together the necessary parts of the ES) and is bundled with all Macintoshes, StellaStack™ (the graphics-based simulation program), and Timbuctu Remote™ (the communication program to allow remote control of the ES). The one-time development cost must be divided between the effort necessary to develop information and to do applied research on the problems covered by the ES, and the additional effort required to package the results of the applied research into an ES format. These costs are estimated to be \$20,000 for the cattle ranching ES and do not include the costs of developing the basic simulation model. Maintenance and training costs are incurred because any complicated system needs to be kept up to date and new personnel must be trained in its use. The present value of these cost streams at a 10% discount rate, assuming a five-year life of the ES and associated hardware, is approximately \$44,000 for one unit and \$52,500 for three units. (Each unit would be located in a different county extension office.)

The benefits to the client derived from the sample ES are significant. A rancher saves \$10 per head per year resulting from changes in management suggested by the ES. For an average ranch with 200 mother cows, this would mean an increase in profits by \$2,000 per year. This result (for Arizona) may be an underestimate; savings of over \$70 per head have been reported for similar integrated management programs elsewhere (see Eftink and Walter).

Because of the complicated nature of providing advice about nutrition management, it was judged that quarterly visits by an extension specialist would be required for a similar level of benefits to be obtained by clients. Thus, the extension budget "savings" from using the ES would equal \$250 per day of specialist time and travel or \$1,000 per year per ranch. For problems which are less complicated, such as providing information on marketing alternatives, the savings would be less as specialist one-on-one input could be obtained over the phone.

The cost effectiveness breakeven point for extension can be roughly calculated in terms of the number of ranches which must use the ES to pay for the model by reducing expenses incurred in providing this training. With just one unit in operation, approximately ten ranches must participate to make the sample ES more effective (in

present value terms) than the "straw man" program. However, with three systems in operation, only two additional participants are needed to cover the marginal cost of the two extra ES units. In the sample project, during the first meeting (at which the basics of the system were introduced) more than ten ranchers from one region indicated strong interest in utilizing the system. Thus, with units located in county offices around the state, the odds of the ES being a cost-effective educational tool for extension are extremely high.

Conclusions and Implications for Extension

The expanded ES approach offers a cost-effective means of extension program delivery. Specialists can make more efficient use of their limited time and travel resources by interacting one-on-one with clients through the computer network connections. They can utilize training materials with multiple clients as the computer system has to be developed only once. In addition, once developed, the ES can serve as a focal point for the collection, organization, and dissemination of information, knowledge, and analytical tools relevant to a subject area. Such a focus serves to facilitate the interaction of specialists in different disciplines towards multi-, inter-, and cross-disciplinary approaches to problem solving. Because of this broad range of advantages, the development of expanded expert systems for delivery of extension programs will be a popular activity for extension faculty in the future. Whether these systems are called expert systems, hybrid expert systems, Intelligent Decision Support Systems, Intelligent Tutoring Systems, computer driven multimedia programs, or the newly popular "hyper something or other," only sound design, based on proven learning techniques, will result in truly effective advances in the delivery of extension programming. The expanded ES described in this paper demonstrates the possibilities of developing educational programs which include the full range of training components, suggesting that this approach holds realistic promise for improving the effectiveness of extension's operations.

The bad news is that there is not a simple evolutionary path between the current way of providing extension programming and large-scale use of expert systems. This is typical of so-called "lumpy" technologies which require major changes for them to be used at all. Because expert systems are a lumpy technology, extension operations without the financial flexibility to invest in the human and computer resources necessary to develop and use these new techniques will continue to fall behind in their ability to deliver relevant and effective programs to their clientele. In some cases the lumpy nature of this innovation will not be recognized, and resources may be diverted into the development of expert systems with restraints attached, such as the requirement that any systems developed must work with the existing set of extension computers. Restraints such as this may reduce the likelihood of being able to develop truly effective expert systems. This leads to questions concerning the optimum path of adoption of expert systems. The answers to these questions are specific to each extension organization and, therefore, will be debated at length.

The analysis presented here, both in terms of learning efficiency and cost effectiveness, strongly suggests that the concept of enhanced expert systems should be an important new addition to the toolbox of extension personnel. If extension is to be an agent of change in the effort to make the agricultural sector more efficient, then advances in technology (which have the potential for making extension itself more efficient) need careful consideration and evaluation. While mass conversion of extension delivery techniques to the ES approach cannot be justified at present, the results for the sample ES suggest that development and implementation of expert systems dealing with some types of problems should proceed and be closely monitored to test their long range effectiveness in delivering extension programming.

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Cholesterol Information and Shell Egg Consumption

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U.S. per capita shell egg consumption has declined steadily since 1955 despite a falling real price. This paper investigates how information about cholesterol, as measured by a newly constructed index based on medical journal articles, has affected U.S. demand for shell eggs. The results of a fixed coefficient model indicate that information on the links between cholesterol and heart disease had decreased per capita shell egg consumption by 16% to 25% by the first quarter of 1987. A simple changing coefficient model indicates that cholesterol information has changed shell eggs' own price and income elasticities, so that the 1955–87 falling egg price and rising income increased egg consumption less than they otherwise would have.

Key words: cholesterol, demand analysis, eggs, health information.

U.S. per capita shell egg consumption has declined steadily since 1955 despite a large downward trend in real price. One suggested reason for the decline is increasing consumer concern with the cholesterol content of eggs (Putler, Schrader et al., Stillman). However, this issue has received little empirical investigation except for Putler's diffusion process model. Putler modeled the effect of cholesterol information on egg consumption by including a nonlinear function of time in the demand equation.[1] He concluded that cholesterol information first had an effect in the second quarter of 1969 and had reduced egg consumption by approximately 14% by the fourth quarter of 1980, with no further reductions between 1980 and 1985.

Time trends long have been used to account for changes in consumer tastes (Stone). More specific data on consumers' changing tastes are difficult to obtain. In the case of eggs, however, one can go beyond a time trend variable to construct a measure of information which may have strongly affected consumer taste for the product. This paper describes the construction of a measure of cholesterol information available to physicians and investigates how this information has affected consumer demand for shell eggs.

Cholesterol Information

The links between cholesterol in the diet and heart disease developed gradually since at least 1963. Initial epidemiological studies linking populations with high fat diets to a high incidence of heart disease (Kato et al.) were countered by other epidemiological studies of populations with high fat diets and a low incidence of heart disease (Biss et al.). Articles indicating a link between dietary cholesterol and blood cholesterol (reviewed by Keys, Grande, and Anderson) were countered by articles that argued against the link (Reiser, Allard et al., Albrink). Even the 1972 joint policy statement by the American Medical Association Council on Foods and Nutrition and the Food and Nutrition Board of the National Academy of Sciences, while recommending that those with elevated blood cholesterol lower their cholesterol consumption, recommended that "high priority be given to the conduct of studies that will determine reliably the extent to which the modification of plasma lipids, by dietary or other means, . . . can reduce the risks of developing coronary artery disease" (p. 1647). At the same time, controversy swirled over the link

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[1] The term in Putler's demand equation is $\exp[(B + \alpha)T] - 1/\exp[(B + \alpha)T] + \beta/\alpha$. T is $\{(t - t^*) + (t + t^*)\}/2$, where t is the current time period and t^* is the time at which cholesterol information begins to affect egg consumption. T is thus zero until period t^* and 1, 2, 3, etc. thereafter. t^*, β, and α are coefficients estimated using nonlinear regression.

between blood cholesterol levels and arteriosclerosis or heart attacks (Benditt 1974, Borhani, Levy, McNamara et al.).

As clinical studies linked cholesterol in the diet to cholesterol in the blood and cholesterol in the blood with mechanisms that damage arteries, the articles in the medical literature became increasingly unambiguous about the importance for at least some part of the population of reducing one type of cholesterol in the diet (e.g., Grundy et al.). Studies of public awareness of possible danger from high cholesterol diets reflect this slow build-up of medical evidence (Scott et al., Ostrander et al.). Shekelle and Liu found that only 13% of a population sampled in 1978 were aware that too much cholesterol or fat in the diet might increase the risk of heart attacks.[2]

Consumers receive health information from many sources including physicians, neighbors, and the popular press. The hypothesis underlying the cholesterol index in this paper is that consumers' attitudes toward cholesterol changed slowly as scientific information accumulated, so a lagged index based on articles in medical journals could serve as a proxy for information reaching consumers from many sources. Because the diffusion of health information is a complex process (Smith, van Ravenswaay, and Thompson), this is a heroic simplification.

The cholesterol index was constructed by first scanning all articles in English dealing with humans and with clinical implications on the Medline data base. Medline is operated by Dialog Information Services. The data base includes materials from approximately 3,200 journals published in over seventy countries. It contains over four million citations for 1966 to 1987. It does not include articles prior to 1966.

Approximately 520,000 human, English, clinical articles are contained in the Medline data base. These were scanned for any connection with cholesterol. Approximately 8,000 of these articles dealt with cholesterol. Many of these articles were considered irrelevant because they focused on smoking, obesity, alcohol abuse, or linked cholesterol with eye, joint, skin, or gall bladder disease. The 8,000 titles were therefore read, and those which did not appear relevant to the links between diet cholesterol, serum cholesterol, and heart disease or arteriosclerosis were discarded. In cases where the content was unclear from the title, the decision to include the article was based on a review of the article's abstract. Approximately 1,000 such abstracts were consulted. All Scandinavian, British, and Canadian articles were discarded based on the belief that they are less likely to be read by U.S. physicians.

The numbers of articles supporting and attacking the linkage were calculated by quarter. A running total, lagged two quarters, was then calculated, with each article supporting the link adding one unit to the total and each article attacking the link subtracting one unit from the total. The equal weighting of pro and anti articles was later supported by the results of a demand equation including the number of articles supporting and the number of articles attacking the link as separate variables; their coefficients were of similar size but opposite in sign in the directions predicted.[3]

There are several ways to model the effect of cholesterol information apart from a simple sum. One might hypothesize that an article's influence will decline over time, as occurs with advertising campaigns. Alternatively, once a link is established, additional articles supporting that link might have little effect. An Almon lag procedure was used to investigate the lag structure of changes in the cholesterol index on egg consumption. It appears that there is a two-quarter lag before a new article has an effect on egg consumption, but the pattern of decay of influence after this initial period is unclear. Articles appear most consistently influential in the first sixteen quarters, but significant coefficients occur up to thirty-two quarters. Lacking a clearly preferable alternative, a simple sum, lagged two quarters, was used as the cholesterol information index. The cholesterol information index is given in table 1.

The Egg Sector: Supply and Demand Specifications

The supply of eggs is relatively simple to model. A pullet chick grows to production age in five months. A layer remains in production for about twelve months unless a molt and rest period are used to induce a second or third laying cycle. A low egg/feed price means a layer becomes

[2] One reviewer suggested that people may know something is bad for them without knowing why it is bad for them.

[3] The coefficient on the lagged sum of articles supporting the links between cholesterol, diet, and heart disease or arteriosclerosis was −.000245 and was different from zero at a 6% significance level. The coefficient on the lagged sum of articles attacking the links was .000524, but it was not different from zero at a 10% significance level.

Table 1. Components of the Cholesterol Information Index

Year	Quarter	Sum of Articles Supporting a Link[a]	Sum of Articles Questioning a Link[a]	Year	Quarter	Sum of Articles Supporting a Link[a]	Sum of Articles Questioning a Link[a]
1955–65		0	0	1977	1	375	10
					2	385	12
					3	392	12
1966	1	0	0		4	400	14
	2	0	0				
	3	8	0	1978	1	406	16
	4	15	0		2	413	16
					3	427	18
1967	1	21	0		4	435	19
	2	27	0				
	3	36	0	1979	1	442	19
	4	50	0		2	452	19
					3	461	19
1968	1	61	0		4	465	21
	2	69	0				
	3	82	1	1980	1	472	22
	4	87	1		2	483	25
					3	491	26
1969	1	94	1		4	499	26
	2	101	1				
	3	107	1	1981	1	508	26
	4	120	1		2	517	26
					3	530	27
1970	1	125	1		4	531	29
	2	132	1				
	3	138	1	1982	1	545	30
	4	143	1		2	558	30
					3	569	31
1971	1	149	1		4	580	33
	2	160	1				
	3	162	1	1983	1	593	33
	4	168	1		2	605	34
					3	615	34
1972	1	174	1		4	627	34
	2	184	1				
	3	191	2	1984	1	646	34
	4	201	2		2	655	35
					3	673	35
1973	1	210	2		4	685	36
	2	215	2				
	3	232	4	1985	1	710	37
	4	239	4		2	726	38
					3	739	39
1974	1	252	4		4	757	39
	2	260	5				
	3	270	6	1986	1	777	39
	4	283	6		2	789	39
					3	822	39
1975	1	292	6		4	846	39
	2	304	6				
	3	316	6	1987	1	866	39
	4	334	7		2	896	39
1976	1	339	7				
	2	345	7				
	3	355	8				
	4	362	9				

Note: The cholesterol information index (*CHOL*) is the sum of articles supporting a link between cholesterol and arterial disease minus the sum of articles questioning such a link.

[a] Lagged six months.

unprofitable at an earlier stage and is withdrawn sooner from laying. The civilian shell egg supply equation is, therefore,

$$(1) \qquad S_C = g(P_C, H, F),$$

where P_C is the real twelve-city metro price for grade A large eggs to retailers; H is a twelve-month moving total of egg type chicks hatched, lagged two quarters; and F is feed cost = .75 (real price in ¢/lb. of No. 2 yellow corn at Chicago) + .25 (real price in ¢/lb. of 44% bulk soybean meal at Decatur). See appendix for data sources.

For the demand specifications, following Smith, van Ravenswaay, and Thompson, a consumer's utility function is expressed as $U(X(Z(N)))$, where X is a vector of goods with qualities Z, and N is information which affects a consumer's perception of the quality of a set of goods. Let consumers' information, N, be a function of the available scientific information, I. This yields a demand equation in which quantity demanded is a function of prices, income, and available scientific information.

Apart from own price, a reasonable demand equation should include the prices of close substitutes. It is not clear which, if any, foods are substitutes for eggs. Huang and Haidacher and Chavas and Johnson found meat a significant substitute, but George and King, Schrader et al., and Stillman did not. Because some investigators have found significant relationships, the price of meat will be included in the demand equation. Most eggs are eaten at breakfast; therefore, bakery and cereals products are also possible substitutes. However, Putler tested and discarded them in his egg demand model, so they were not used in this model.

The cholesterol information index described above represents the available scientific knowledge. Two other variables which reflect changing tastes are also included in the demand equation: percentage of women in the workforce and time. Stillman suggested that the increase in the percentage of women working outside the home may have reduced the quantity of eggs served for breakfast at home because of time constraints. On the other hand, more working women might mean more breakfasts eaten away from home. Surveys for the American Egg Board indicate that egg consumption away from home has been increasing since the late 1970s. Although the anticipated relationship is ambivalent, quarterly values for the percentage of women who are in the labor market, WW, represent this structural change.

Time is the black box of structural change. Its use indicates a recognition of structural change without the ability to identify, or perhaps obtain data on, the cause. The time variable here is the number of the quarter from 1 in the third quarter of 1955 to 128 in the second quarter of 1987.

The civilian demand for shell eggs used in this analysis is[4]

$$(2) \qquad D_C = f(P_C, P_S, Y_C, Q_2, Q_3, Q_4, CHOL, WW, TIME),$$

where D_C is the civilian disappearance of shell eggs (production − change in stocks − hatching use − eggs broken + imports − exports − military use); P_C is the real twelve-city metro price for grade A large eggs to retailers; P_S is the real price of meat; Y_C is real civilian per capita income; Q_2, Q_3, Q_4 are quarterly dummies to account for changes in seasonal demand; $CHOL$ is the cholesterol information index; WW is the percentage of women in the labor force; and $TIME$ is the quarter number.

Estimation Results

The estimation results reported in this section represent model specifications for both constant and changing coefficients.

Constant Coefficients

Supply and demand equations were expressed in per capita terms and assumed to be variants of a double log. The resulting equations are:

$$(3) \qquad \log(S_C/N) = C_0 + C_1 \log P_C + C_2 \log H + C_3 \log F, \text{ and}$$

$$(4) \qquad \log(D_C/N) = b_0 + b_1 \log P_C + b_2 \log P_S + b_3 \log Y_C + b_4 Q_2 + b_5 Q_3 + b_6 Q_4 + \sum_k b_k \text{ structural variable}_k.$$

[4] Military demand, exports and imports, and eggs for breaking are not estimated in this study. The military have historically consumed more eggs per capita and are unlikely to be affected in the same way by structural change. Military consumption has recently averaged less than 1/2% of total egg production. Exports and imports are typically less than 2% of egg production, and they are heavily influenced by policies in other nations. Eggs for breaking are sold liquid, dried, or frozen to food manufacturers and food service institutions. Unlike shell eggs, this demand has increased since 1955. The price of eggs for breaking is highly correlated with the price of shell eggs.

The demand equation was estimated using weighted two-stage least squares as described by Kmenta (pp. 705–8) to correct for simultaneity and first-degree autocorrelation. The Box-Cox transformation technique was used to test the appropriateness of the double-log form. The results supported the use of a loglinear form rather than a linear form.[5]

The results for all possible combinations of structural change variables are shown in table 2. These combinations allow one to observe the effect of removing various structural variables on the size and sign of the remaining coefficients.

Initially, egg demand was estimated using data from 1966–87, the period in which the cholesterol information index could be calculated. However, severe multicolinearity occurred between time and women in the workforce, time and income, and time and the cholesterol information index (ρ greater than .98 for all). Thus, egg demand was reestimated using data from 1955 to 1987 assuming that the cholesterol information index was zero prior to 1966. This assumption seems permissible given Putler's estimate, using 1960–85 quarterly data and a nonlinear time trend, that cholesterol concerns first began to have an effect in 1969. Table 3 shows the Pearson correlation coefficients for this expanded data set. Large correlations still occur between income and time, women working and time, and women working and the cholesterol information index; however, the problem is less severe than when only 1966–87 data were used.

Price is expected to have a negative effect on per capita egg demand. Huang and Haidacher recently obtained an annual own-price elasticity of −.14. Other own-price estimates, summarized in Chavas and Johnson, range from −.092 to −.40. This study's quarterly own-price elasticity ranged from −.02 to −.17. depending on the structural variables included in the equation. The model with all structural variables included had an own-price elasticity (−.17) similar to Huang and Haidacher's and significantly different from zero at the 1% level.

The expected sign on the income coefficient is not clear a priori. Huang and Haidacher obtained an annual expenditure elasticity of −.06, but it was not significantly different from zero. This study obtained a negative income elasticity for 1966–87 which was not different from zero at a 5% significance level. The income elasticity

[5] The Box-Cox power transformation is $y(\lambda) = \begin{cases} (y^{\lambda}-1)/\lambda & \lambda \neq 0 \\ \ln y & \lambda = 0 \end{cases}$. The log-likelihood function for $\lambda = 1$, the linear transformation, was −80.1. The loglikelihood function for $\lambda = 0$, the log transformation, was −42.7.

Table 2. Regression Coefficients for Per Capita Civilian Shell Egg Demand with Different Shifter Variables Included; 1955–87 and 1966–87 Data

	TIME	*WW*	*CHOL*	$\ln P_c$	$\ln Y_c$	ln*Meat Price*	$\bar{R}^2$
No structural variables				−.022	−.50***[a]	.004	.898
One structural variable	−.0055***			−.094	.24	.053	.960
		−.010***		−.043	−.35***	.040	.922
			−.00031***	−.089	−.29***	.054	.932
Two structural variables	−.0055***	−.004*		−.129**	.28***	.082	.960
	−.0056***		−.00014***	−.164***	.33***	.099	.968
		−.004***	−.00026**	−.109	−.27***	.078	.932
All structural variables	−.0059***	.0018	−.00017***	−.17***	.35***	.102*	.968
Regression Coefficients for Per Capita Shell Egg Demand: 1966–87 Data							
All structural variables	−.0029***	.010***	−.00027**	−.067*	−.11	.033	.965

[a] Single asterisk indicates significant at the 10% level; double asterisk indicates significant at the 5% level; triple asterisk indicates significant at the 1% level.

Table 3. Pearson Correlation Coefficients, 1955–87 Data

	$\ln P_c$	$\ln Y_c$	*WW*	*CHOL*	ln*Meat Price*	*TIME*
$\ln P_c$	1.00					
$\ln Y_c$	−.83	1.00				
WW	−.87	.96	1.00			
CHOL	−.86	.93	.98	1.00		
ln*Meat Price*	.13	.20	.12	.08	1.00	
TIME	−.86	.99	.98	.95	.15	1.00

for 1955–87 was negative only when *TIME*, which is closely correlated with income in this period, was omitted from the demand equation.

Huang obtained annual cross-price elasticity estimates for eggs of .047 for beef and veal, −.02 for pork, and −.0075 for other meat; however, none of these were significantly different from zero at a 10% level. In this study, cross-price elasticities for all meat ranged from .004 to .10. Only when *TIME*, *WW*, and *CHOL* were included in the equation was the coefficient on meat prices different from zero at a 10% level.

The seasonal dummy variables, not shown in table 2, were significantly different from zero regardless of which structural change variables were included.

The choice among structural change variables is difficult. Before considering the empirical results, one can argue that both *WW* and *CHOL* have changed the demand for eggs, and that other structural changes could best be captured by *TIME*. Moreover, the effects of the different structural variables would be difficult to distinguish empirically because they, along with per capita egg consumption and per capita real income, are all strongly trended variables in the sample period.

The $\bar{R}^2$ is highest if two or three shifters are included in the demand equation, but the differences in $\bar{R}^2$ are not great once one shifter is included. The coefficients on *TIME* and *CHOL* are both consistently and significantly negative. The coefficient on women in the workforce for 1955–87 is only significant at a 5% level if *CHOL* is omitted from the equation. Moreover, its omission does not greatly affect the signs, sizes, or significance levels of the other variables in the equation for this period. However, the coefficient on women in the workforce is positive and different from zero at a 1% significance level for 1966–87.

When nonnested hypothesis tests (Kmenta, pp. 595–98) were used to compare equations with two structural variables, none of the equations dominated another. The predicted value from each equation was significant at the 1% level in every other equation. This result suggests that all three structural variables should be included in an egg demand model.

Estimation of the demand equation with all structural change variables included for 1955–87 indicates that cholesterol information had decreased per capita shell egg consumption by 16% by the first quarter of 1987. Estimation using only the 1966–87 period indicates that cholesterol information had decreased per capita shell egg consumption by 25% by the first quarter of 1987.

A recursive estimation technique was used on the equation containing all structural change variables to explore the stability of the *CHOL* coefficient over time (Brown, Durbin, and Evans; Dufour). The *CHOL* coefficient was negative and different from zero at a 5% significance level after 1974. The *CHOL* coefficient declined in absolute value after 1983. The decline is expected if additional medical articles on cholesterol began to have a declining effect on egg consumption. One might hypothesize that, as knowledge accumulates, the importance of new articles on cholesterol which merely confirm previous articles should decline.

The equation with all structural change variables was reestimated with the addition of the variable *CHOL-SQUARED* to further explore a possible declining effect of cholesterol articles. The estimated coefficient on *CHOL-SQUARED* was not different from zero at a 10% significance level.

Changing Coefficients

The effect of cholesterol information can be modeled in alternative ways. One possibility is to assume that price and income coefficients are not fixed but vary with the cholesterol index:

$$(5)\quad (D_c/N) = b_0 P_c^{b_1} Y^{b_2} P_S^{b_3} Q_2^{b_4} Q_3^{b_5} Q_4^{b_6} WW^{b_7} TIME^{b_8},$$

where $b_1 = f_1(CHOL)$ and $b_2 = f_2(CHOL)$. If one assumes that f_1 and f_2 are simple linear functions: $b_1 = a_0 + a_1 CHOL$ and $b_2 = d_0 + d_1 CHOL$, taking logs of both sides yields equation (6).

$$(6)\quad \ln(D_c/N) = b_0 + a_0 \ln P_c + a_1(CHOL \cdot \ln P_c) + d_0 \ln Y_c + d_1(CHOL \cdot \ln Y_c) + b_3 P_S + b_4 Q_2 + b_5 Q_3 + b_6 Q_4 + b_7 WW + b_8 \ln Meat\ Price + b_9 TIME.$$

When estimated using the 1955–87 data, this specification yielded

$$(7)\quad \ln(D_c/N) = \underset{(3.00)}{2.04} - \underset{(-3.3)}{.265}\ \ln P_c - \underset{(-6.7)}{.007}\ TIME + \underset{(4.4)}{.355}\ \ln Y_c - \underset{(-8.4)}{.069}\ Q_2 - \underset{(-10.5)}{.049}\ Q_3 + \underset{(5.4)}{.020}\ Q_4 + \underset{(1.5)}{.004}\ WW + \underset{(2.0)}{.096}\ \ln meat\ price + \underset{(1.8)}{.00017}\ (\ln P_c \cdot CHOL) - \underset{(-2.2)}{.00009}(\ln Y_c \cdot CHOL),$$

where t-statistics are in parentheses. The coefficients on the interaction terms ($P_c \cdot CHOL$) and $Y \cdot CHOL$) are different from zero at, respectively, 10% and 5% significance levels.

The positive interaction of egg price and cholesterol seems to indicate that cholesterol information has decreased the absolute price elasticity of shell eggs in this period. As real egg prices dropped, egg consumption increased less than would be the case without cholesterol information. The negative interaction of income and cholesterol suggests that cholesterol information has also decreased the income elasticity of shell eggs in this period. As income rose, egg consumption increased less than would have occured without cholesterol information. According to these results, cholesterol information decreased per capita egg consumption by 16% by the second quarter of 1987 using 1955–87 data.

Conclusions

This paper described the construction of a cholesterol information index based on citations of the link between cholesterol and arterial disease in medical journals. When the index was used to predict per capita shell egg demand in a fixed coefficients regression, its coefficient was always negative and different from zero at a 1% significance level regardless of other variables included in the regression. Moreover, the resulting estimates of price and income elasticities were plausible. In a variable coefficients model which specified price and income elasticities as functions of cholesterol information, the presence of cholesterol information decreased the absolute own-price and income elasticities of the demand for shell eggs. As egg prices dropped, shell egg consumption increased less than would have been the case without the cholesterol information. Similarly, as income rose, consumption increased less than it would have without cholesterol information. Thus, information about cholesterol appears to have had a substantial effect, decreasing per capita civilian shell egg consumption by 16% to 25% by the first quarter of 1987, depending on the data period used.

A logical extension of this analysis would consider the performance of the cholesterol index in demand equations for red meat and poultry, for various fats, and for dairy products; these products may also have experienced structural changes in demand as consumers' information about cholesterol changed. This study provides evidence that the stock and dissemination of health information may need to be considered when food demands are estimated.

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Appendix

Other Data Sources

D_c	Civilian disappearance of shell eggs	*Livestock and Poultry: Situation and Outlook*
H	Twelve-month moving total of eggs type chicks hatched	*Livestock and Poultry: Situation and Outlook*
P_c	Twelve-city metro real price for Grade A large eggs to retailers	Calculated from unpublished USDA data and *Egg and Poultry Statistics Through Mid-1972*
Y_c	Per capita real income	Calculated from data in *Survey of Current Business*
WW	Percent of female noninstitutionalized population in the labor force	Bureau of Labor Statistics, *Employment and Earnings* and *Monthly Report on the Labor Force*
F	Feed cost	Calculated from data in *Grain and Feed Market News* and *Fats and Oils Situation*
P_S	Real meat price index	*Monthly Labor Review*

Testing Restrictions on a Model of Japanese Meat Demand

Dermot J. Hayes, Thomas I. Wahl, and Gary W. Williams

Tests for quasi-separability, net substitutability, and perfect substitutability are developed and implemented on an almost ideal demand system model of the Japanese meat sector. The data set satisfies both symmetry and homogeneity. There is evidence of net complimentarity between chicken and dairy beef and chicken and pork. The tests indicate that Japanese Wagyu beef is considered a separate commodity to both imported beef and dairy beef. The results also indicate that fish can be treated as separable in the Japanese meat demand system.

Key words: demand analysis, Japanese meat preferences, separability.

Japanese imports of beef have grown slowly over the years because of a restrictive Japanese beef import policy. A 1988 agreement between the United States and Japan, however, will significantly curtail Japanese intervention in its beef market in the future and force the Japanese cattle industry to adjust to greater market determination of the supply, demand, and prices of beef. Although research on the economic effects of Japanese beef policy has been growing (e.g., Hayami; Anderson; Wahl, Williams, and Hayes), a clearer understanding of the Japanese meat sector is needed to measure more precisely those effects. In this paper, a model of the Japanese meat demand system is estimated and used to test three hypotheses regarding meat consumer behavior in Japan. The tests were developed specifically for the linear approximate almost ideal demand system (LA/AIDS) used in this study.

The first hypothesis tested is that fish is not separable from meat in Japan and, therefore, should be included in the Japanese meat system. The role of fish in purchase decisions of Japanese meat consumers has been controversial. A test for quasi-separability of the cost function for the AIDS is developed and used to test the hypothesis. The test provides modelers with a general method to choose groups of commodities that belong together in a separable model. This is particularly important when modeling demand systems of foreign markets where social and cultural differences affect dietary habits and preferences.

The second hypothesis tested is that imported beef is a perfect substitute for beef from the native beef breed. The test is important because the extent of any impact of changes in Japanese beef policy will depend crucially on the degree of substitutability of beef types in Japan. The final hypothesis is that all meats in Japan are net substitutes in consumption. Here a Bayesian procedure recently developed by Geweke is used to impose restrictions on the Hicksian cross-price elasticities. The test is quite useful because unexpected findings of complementarity among related commodities in demand system studies is common. Incorporating a demand system with such complementarities present into larger simultaneous system commodity models can lead to counterintuitive policy simulation results.

The first section of this paper describes the Japanese meat sector and highlights the differences between the United States and Japan. The second section presents the results of the LA/AIDS model of the Japanese meat sector. Tests of the three hypotheses regarding demand behavior in the Japanese meat sector are constructed and the results discussed. The final section offers some summary comments on the major results.

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Overview of the Japanese Meat Sector

Japanese cattle inventories include the native (Wagyu) beef breed and dairy cattle. A large number of farmers raise small herds of Wagyu as a sideline to crop production. In contrast, dairy farming is a highly specialized activity. Herds are correspondingly larger. However, both Wagyu and dairy calves are fattened for slaughter. A rapid increase in per capita income in Japan has resulted in a rapidly increasing demand for beef. On average over the last twenty years, however, the per capita consumption of beef has not expanded nearly as rapidly as that of pork or chicken meat. In 1965, for example, the per capita consumption of beef, pork, and chicken meat were nearly equal at about 1 or 2 kilograms per year (retail cuts basis). By 1986, per capita pork and chicken meat consumption had jumped to 9.9 kilograms per year and 9.8 kilograms per year, respectively, compared with that of beef at only 4.1 kilograms per year (retail cuts basis). Given the historically restrictive beef import quota, this disparity in growth rates reflects a similar disparity in relative rates of growth in production and an opposite disparity in price movements over time. The more rapid production growth of pork and chicken meat has been caused primarily by the rapid adoption of modern confinement feeding technology for hogs and chickens in Japan over the last twenty years. Thus, although the real retail price of beef in Japan increased by 17% between 1965 and 1986, those of pork and chicken meat decreased by 43% and 56%, respectively. The Japanese consume significantly more fish than do Americans, which is reflected in the fact that the Japanese spend as much on marine products as they do on beef, pork, and chicken meat combined.

Imported beef is more lean than the beef produced from Japanese cattle. The Japanese place great emphasis on the degree of marbling in beef cuts. Japanese milk producers run a profitable sideline by fattening their holstein calves to weights that are similar to those of U.S. choice steers. There is reportedly much greater similarity between the beef imported from the United States and Japanese dairy steer beef than between imported U.S. beef and Wagyu steer beef (Mori, Gorman, and Faminow).

A Model of the Japanese Meat Demand System

Given the perceived differences between U.S. and Japanese beef, import-quality beef and Wagyu beef are treated as separate commodities in the model.[1] The validity of this assumption is tested in the third section of this paper. This is a significant distinction because the principal Japanese justification for restricting beef imports is that increases in beef imports reduce the profitability of Wagyu production. This implicitly assumes that Wagyu beef and U.S. beef are perfect or at least very close substitutes.

The LA/AIDS technique was chosen to estimate the parameters of the Japanese meat demand system. It combines the best of the theoretical features of both the Rotterdam and translog models with the ease of estimation of the Linear Expenditure System (LES). The LA/AIDS provides an arbitrary first-order approximation to any demand system, satisfies the axioms of choice exactly, and, under certain conditions, aggregates perfectly over consumers (Deaton and Muellbauer 1980a, b). In addition, the LA/AIDS is directly nonadditive (Blanciforti and Green 1983a). Although LA/AIDS does not implicitly impose the theoretical restrictions of homogeneity, Slutsky symmetry, and adding up, these restrictions can be imposed easily. These last two characteristics are particularly important for an analysis of Japanese meat demand. Use of a directly additive system such as the LES would imply independent marginal utilities between Wagyu and import-quality beef.

The expression for the budgetary share (W) allocated to the ith meat item in the LA/AIDS is

$$(1) \quad W_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln P_j + \beta_i \ln\left(\frac{X}{P}\right),$$

where P_j is the price of meat j, X is the per capita expenditures on all five meats, and P is a suitable price index.[2] For P, Deaton and Muellbauer suggest using Stone's index (defined as $\ln P = \sum_{i=1}^{n} W_i \ln P_i$).

Adding up, homogeneity, and Slutsky symmetry can be imposed on this system as follows:

$$(2) \quad \sum_{i=1}^{n} \alpha_i = 1; \sum_{i=1}^{n} \gamma_{ij} = 0; \text{ and } \sum_{i=1}^{n} \beta_i = 0;$$

$$(3) \quad \sum_{j} \gamma_{ij} = 0; \text{ and}$$

[1] Import-quality beef is defined as either Japanese dairy beef or imported beef.

[2] Because we use the expenditure on meats rather than total expenditures, the resulting system is a conditional one. The elasticities are all second-stage estimates.

(4) $\gamma_{ij} = \gamma_{ji}$.

Provided that equations (2), (3), and (4) hold, the estimated demand functions add up to the total expenditure (2), are homogenous of degree zero in prices and income taken together (3), and satisfy Slutsky symmetry (4) (Deaton and Muellbauer 1980a, p. 314).

The expenditure and price data are from various yearbooks and reports published by the Japanese Ministry of Agriculture, Forestry, and Fisheries (MAFF). These publications include various issues of *Statistical Yearbook, Statistics of Meat Marketing, Meat Statistics in Japan, Monthly Statistics of Agriculture, Forestry,* and *Fisheries,* and the *Annual Report on the Family Income and Expenditure Survey*. Expenditures are calculated as price times disappearance (retail basis). Disappearance for Wagyu beef, import-quality beef, pork, and chicken are calculated as production plus imports, which are available from the *Statistical Yearbook*. Retail fish disappearance is also available from the *Statistical Yearbook*. Retail prices for pork and chicken meat are from *Meat Statistics in Japan*. Retail fish price, from the *Annual Report on the Family Income and Expenditure Survey,* is an average of fresh and salted fish price series weighted by the disappearance of each.

A retail beef price is available in the *Meat Statistics in Japan,* but individual retail prices for Wagyu and dairy beef are not published. Retail Wagyu and dairy beef prices are calculated by multiplying the respective wholesale prices available in *Statistics of Meat Marketing and Meat Statistics in Japan* by 2.1156. This coefficient is the average ratio of total retail beef expenditures to the sum of wholesale Wagyu beef expenditures and wholesale dairy beef expenditures. (See Wahl for further details on the data and sources.)

Because the meat expenditure shares (W_i) sum to one, a demand system composed of the five individual expenditure share equations would be singular. Therefore, one of the equations must be dropped to estimate the equations as a system. The fish share equation was chosen for deletion in this study. However, the parameters for the omitted share equation can be calculated by using the adding-up restrictions from (2). In the absence of other restrictions, these restrictions are costlessly imposed. That is, the omitted share equation parameters calculated by using the restrictions are identical to those that would be estimated directly by using ordinary least squares (OLS). In the remainder of this paper, estimates of the parameters of the expenditure system were derived by using an iterated nonlinear, seemingly unrelated regressions (ITSUR) estimator.[3] As suggested by Berndt and Savin, the system was corrected in each case for autocorrelation by using the same autocorrelation coefficient for each equation. These procedures provide maximum likelihood estimates that are invariant to the equation chosen for deletion (Chalfant).

Slutsky symmetry was then imposed on the parameters of the system. Because symmetry cannot be tested equation by equation, a test statistic, such as the asymptotic likelihood ratio, for the system as a whole is required. The imposition of Slutsky symmetry automatically imposes homogeneity in the LA/AIDS (McKenzie and Thomas). Consequently, the unrestricted model for testing Slutsky symmetry alone had homogeneity imposed. Slutsky symmetry was accepted at the 5% level.

Both Marshallian and Hicksian measures of elasticities can be computed from the estimated parameters of the LA/AIDS model as follows:

(5) $\epsilon_{ii} = -1 + \gamma_{ii}/W_i - \beta_i,$

(6) $\epsilon_{ij} = \gamma_{ij}/W_i - \beta_i(W_j/W_i),$

(7) $\delta_{ii} = -1 + \gamma_{ii}/W_i + W_i,$ and

(8) $\delta_{ij} = \gamma_{ij}/W_i + W_j,$

where ϵ denotes Marshallian elasticities and δ denotes the income-compensated, or Hicksian, measure. These formulas were derived from the LA/AIDS equation with total meat expenditures rather than total expenditures in the numerator of the last term. Expenditure elasticities can be obtained as well:

(9) $\eta_i = 1 + \beta_i/W_i.$

These elasticities have been calculated for the demand system with Slutsky symmetry imposed and are presented along with their standard errors in table 1. The standard errors (in parentheses) were calculated by using the method proposed by Chalfant. This method assumes that budget shares are exogenous; consequently, the standard errors are only approximations. For comparative purposes, Chalfant's estimates of similar elasticities for the United States are also presented in table 1. Chalfant employed a nearly

[3] The ITSUR estimator used is an option in the SYSNLIN procedure of the Statistical Analysis System (SAS) software.

Table 1. Japanese and U.S. Meat Data: Price and Expenditure Elasticities

Type Expenditure	Hicksian Elasticities for Japan Household Model		Hicksian Elasticities for Japan Per Capita Model		Marshallian Elasticities for Japan Per Capita Model		Marshallian Elasticities for the United States Per Capita Model[a]	
Wagyu beef demand								
Wagyu beef	−1.79	(0.31)	−1.78	(0.30)	−1.89	(0.30)		
IQ beef	0.28	(0.22)	0.23	(0.21)	0.12	(0.21)		
Pork	0.98	(0.32)	0.98	(0.33)	0.64	(0.30)		
Chicken	0.55	(0.20)	0.50	(0.21)	0.31	(0.19)		
Fish	−0.03	(0.69)	0.06	(0.70	−1.00	(0.58)		
Expenditure	2.28	(0.87)	1.83	(0.74)	1.83	(0.74)		
IQ beef demand								
Wagyu beef	0.25	(0.19)	0.21	(0.20)	0.06	(0.19)		
IQ beef	−0.37	(0.23)	−0.29	(0.23)	−0.46	(0.22)	−0.37	(0.03)
Pork	0.12	(0.28)	0.18	(0.29)	−0.28	(0.25)	0.27	(0.30)
Chicken	−0.37	(0.17)	−0.24	(0.18)	−0.50	(0.16)	0.08	
Fish	0.36	(0.68)	0.13	(0.69)	−1.32	(0.54)	0.02	(0.12)
Expenditure	2.26	(0.81)	2.49	(0.68)	2.49	(0.68)	1.28	(0.05)
Pork								
Wagyu beef	0.31	(0.10)	0.31	(0.11)	0.28	(0.09)		
IQ beef	0.04	(0.10)	0.06	(0.10)	0.03	(0.08)	0.52	(0.01)
Pork	−0.67	(0.23)	−0.66	(0.24)	−0.76	(0.16)	−0.67	(0.03)
Chicken	0.13	(0.12)	−0.11	(0.13)	−0.17	(0.07)	0.10	
Fish	0.45	(0.60)	0.40	(0.61)	0.09	(0.27)	0.04	(0.06)
Expenditure	0.29	(0.40)	0.53	(0.35)	0.53	(0.35)	0.99	(0.07)
Chicken demand								
Wagyu beef	0.32	(0.11)	0.28	(0.12)	0.19	(0.10)		
IQ beef	−0.23	(0.11)	−0.15	(0.12)	−0.25	(0.09)	0.34	
Pork	−0.24	(0.22)	−0.20	(0.22)	−0.50	(0.14)	0.24	
Chicken	−0.56	(0.16)	−0.42	(0.17)	−0.59	(0.14)	−0.51	
Fish	0.72	(0.61)	0.49	(0.62)	−0.43	(0.32)	−0.07	
Expenditure	1.15	(0.48)	1.60	(0.42)	1.60	(0.42)	0.21	
Fish								
Wagyu beef	−0.01		0.01		−0.04			
IQ beef	0.04		0.02		−0.04		0.19	(0.02)
Pork	0.14		0.13		−0.02		0.16	(0.02)
Chicken	0.13		0.09		0.01		−0.12	
Fish	−0.31		−0.24		−0.70		−0.23	(0.13)
Expenditure	0.92		0.79		0.78		0.15	(0.25)

Note: IQ beef is import-quality beef, which includes both imported and domestic dairy beef. All models have Slutsky symmetry and homogeneity imposed. Numbers in parentheses are standard errors. The parameters of the fish expenditure share equation are calculated by using the adding-up restriction.

[a] Source of U.S. per capita model Marshallian elasticities is Chalfant.

identical estimation procedure to the one used here using annual data from 1947 to 1978.

Almost all empirical applications of the AIDS model deflate total expenditures by population. This is not strictly correct. The exact aggregation property of the AIDS model is based on a household cost function and not on individual members of the household. Also, the assumption of weak separability is more intuitively appealing in the context of household budgets rather than those of individuals. Deaton and Muellbauer (1980a) acknowledge this and present the version of the model that satisfies exact aggregation:

$$(10)\qquad \bar{W}_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \log P_j + \beta_i \ln(\bar{X}/kP),$$

where $\bar{W}_i$ is the share of aggregate expenditure on good i in the aggregate budget of all households and $\bar{X}$ is the average level of household expenditure. The index k, known as the household income equivalence scale (Muellbauer), is a sophisticated theoretical construct defined by

$$\log \bar{X}/k \equiv \sum_{n} X_h \log(X_h/k_h)/\Sigma X_h,$$

where X_h is the expenditure level of individual

households and k_h can be defined as the household specific income deflator, which must be used so that all households have the same budget shares as a reference household for which $k = 1$. Accurate measurement of k, if possible, would be very expensive. As a consequence, the index is ignored in empirical studies. If k is assumed to be closely correlated with household size, the common practice of deflating total expenditure by total population is defensible. Even if this were the case, however, the number of people per household would have to remain constant as real expenditures increase to avoid an omitted variable bias (Deaton and Muellbauer 1980a, p. 315). Unfortunately, average household size in Japan has fallen as real expenditures have increased. Without an accurate measure of the household specific deflator, it is impossible to measure this bias. Consequently, table 1 presents two sets of Hicksian elasticities from the demand system in which population and household numbers, respectively, have been used as expenditure deflators. The per capita demand system was used in the rest of the paper to facilitate comparison with the results of other AIDS models.

The estimated elasticities in this study for the Japanese meat demand system are, in general, in accordance with a priori expectations. All own-price elasticities are negative while most of the compensated cross-price elasticities are positive. The results, however, suggest that chicken is a complement of import-quality beef and perhaps pork. This conclusion is not the case for Chalfant's estimates for the United States, which indicate that chicken is complementary only to fish. Note that, for all relevant meats, the (Marshallian) own-price elasticity of demand is greater in Japan than in the United States.

The estimated expenditure elasticities indicate that both Wagyu and import-quality beef are luxury goods in Japan (table 1). When total population is used to deflate expenditures, the expenditure elasticity of demand for import-quality beef was greater than that for Wagyu beef. This latter result is somewhat surprising because Wagyu beef is much more expensive than import-quality beef. Japanese consumers consider Wagyu beef to be more desirable than imported beef (Miyazaki). Nevertheless, the import-quality beef expenditure share more than doubled over the sample period, while that of Wagyu beef was virtually constant over the sample period. Teal et al. also find that the income elasticity of demand for low-quality beef is above that for high-quality beef in Japan.

The income elasticity of Japanese demand for meats was estimated to be 1.54 by Sasaki and Fukagawa. A 10% increase in real income, therefore, implies that the demand for import-quality beef would increase by almost 40%. This figure was derived by multiplying the per capita expenditure elasticity for import-quality beef by the income elasticity of demand for the meat group as a whole (Blanciforti and Green 1983b).

The Japanese expenditure elasticities for both poultry and fish are greater than the pork expenditure elasticity. Again, this is not the case in the Chalfant study of the United States, where poultry has the lowest expenditure elasticity of all meats. The implication is that pork occupies the same position in Japanese spending priorities as poultry does in the United States.

Testing Hypotheses About the Japanese Meat System

In this section, tests of three hypotheses concerning meat consumer behavior in Japan are developed and applied to an LA/AIDS model for the Japanese meat sector. The hypotheses relate to the (*a*) separability, (*b*) perfect substitutability, and (*c*) net substitutability of meats in Japan. The results provide insight into demand systems modeling in general and the Japanese meat system in particular.

Testing for Separability in an AIDS Model

Japanese consumers spend almost as much on fish as they spend on all other meats combined. In addition, the government collects much more detailed data on consumption and prices of different fish species than on meats. Defining "fish" as a single commodity in a meat demand system, rather than defining several subcategories of fish as was done with red meats, reflects a Western bias. However, data limitations preclude the estimation of a model with individual red meats and individual fish species. The possibility remains, however, that fish should be considered as separable from other meats at a more aggregate level. This section demonstrates how this separability hypothesis can be tested by using parametric restrictions on the AIDS model.

Separable demand models have been developed by Barten (1964, 1968), Brown and Heien, Jorgenson and Lau, and Barnett. Where tested in these highly aggregated models, separability restrictions have been rejected. Eales and Un-

nevehr derive a restriction which they use to test for weak separability in a first-difference AIDS model.[4]

Many concepts of separability are in use, including the distinction as to whether there is weak or strong separability, separability of the utility function (direct), separability of the indirect utility function (indirect), separability of cost or distance function (quasi), separability of an implicit representation of the direct utility function (direct pseudo), and, finally, separability of an implicit representation of the indirect utility function (indirect pseudo). Pudney provides a formal definition of each and uses each to impose and test separability in a simple constant elasticity model. Although each definition requires a different set of parametric restrictions, Pudney shows that the various definitions available make little difference to the empirical results. Consequently, only quasi-separability of the cost function was tested in the Japanese meat AIDS model. This approach was chosen because AIDS is based on a flexible functional form of the cost function.

Assume that $M = G^*(p, u)$ is an arbitrary definition of the cost function that gives the minimum cost (M) of reaching indifference curve u at price p. This function is assumed to be concave, homogenous of degree one in p, and increasing. For such an arbitrary cost function, preferences are said to be quasi-separable if the function can also be written as

$$M = G[g_1(p_1, u), \ldots, g_r(p_r, u)], \tag{11}$$

where $G(\cdot)$ and the functions $g_r(\cdot)$ also have the general properties of cost functions, goods are portioned into r groups with price subvectors $p_1 \ldots p_r$, and the functions $g_r(p_r, u)$ are increasing in u and G (Gorman). Deaton and Muellbauer (1980b, p. 134) discuss separability of this type (which they term implicit separability) and show that the group budget shares ($W_r = X_r/X$) may be derived from

$$W_r = \frac{\partial \ln G}{\partial \ln g_r}. \tag{12}$$

Intragroup budget shares ($W_{ri} = q_i p_i / X_r$) may be derived from

$$W_{ri} \equiv \frac{\partial \ln g_r(p_r, u)}{\partial \ln p_{ri}}, \tag{13}$$

where $g_r(p_r, u)$ can best be considered "as group price indices that depend on the level of utility u" (Deaton and Muellbauer 1980b, p. 134). Each vector p_r is composed of the prices of the individual i commodities within the group r.

From Shephard's lemma, the share of subgroup i within X (total group expenditures), or $W_{Gi} \equiv q_i p_i / X$, may be derived from

$$W_{Gi} = \frac{\partial \ln G}{\partial \ln g_r} \frac{\partial \ln g_r}{\partial \ln p_{ri}} = W_r W_{ri}. \tag{14}$$

Differentiating (16) with respect to the price of good j in group S (P_{sj}) and holding u constant, the form of the between-good Slutsky terms can be derived as follows:

$$\gamma_{risj} = \frac{\partial W_{Gi}}{\partial P_{sj}} = \frac{\partial^2 \ln G}{\partial \ln g_r \partial \ln g_s} \frac{\partial \ln g_r}{\ln p_{ri}} \frac{\partial \ln g_s}{\partial \ln p_{sj}}. \tag{15}$$

Taking each variable on the right-hand side of (17) in turn,

$$\text{(i)}\ \frac{\partial \ln G}{\partial \ln g_r} = W_r \quad \text{(ii)}\ \frac{\partial \ln W_r}{\partial \ln g_s} = \gamma_{rs}$$

$$\text{(iii)}\ \frac{\partial \ln g_r}{\partial \ln p_{ri}} = W_{ri} \quad \text{(iv)}\ \frac{\partial \ln g_s}{\partial \ln P_{sj}} = W_{sj},$$

where γ_{rs} is the estimated cross-price parameter between groups r and s, estimated from an aggregate AIDS model that has shares W_r and W_s as dependent variables. This result (ii) is derived by specifying an equation for share r and taking the derivative with respect to the group price index holding the level of utility (or X/P) constant. Hence, the restriction that is implied by quasi-separability of the cost function may be written in terms of known shares and estimated parameters as

$$\gamma_{risj} = W_{ri} W_{sj} \gamma_{rs}. \tag{16}$$

In other words, two groups, r and s, may be considered separable if the compensated cross-price effects between the share of good i in group r and the price of good j in group s ($s \neq r$) satisfy the restriction in (16). For Japan, W_{ri}, W_{sj}, and γ_{rs} may be respectively considered to be the share of each meat of nonfish meat expenditures, the expenditure share for a particular fish within the fish group, and the cross-price parameter between the meats and fish in a more aggregate AIDS model. Because one aggregate fish group is used, W_{sj} can be set to 1 so that the restriction becomes

$$\gamma_{ris} = W_{ri} \gamma_{rs}. \tag{17}$$

[4] The technique in this paper differs from that used by Eales and Unnevehr in that the former allows comparison of restricted and unrestricted parameters whereas the latter does not.

The procedure for implementing this restriction is straightforward. An estimate of γ_{rs} was obtained by using a two-good AIDS model to explain the shares of meat and fish. A second model was then estimated in which individual meat shares and fish group share were dependent variables. The predicted shares of the individual meats within the meat groups were multiplied by γ_{rs} to obtain a set of parametric restrictions that were then placed on the cross-price terms between each meat price and the fish group price. A likelihood ratio test was then performed to determine if the restrictions were accepted by the data. The calculated likelihood ratio, which has a chi-square distribution, was 6.20. The 5% significance level of the chi-square distribution with four restrictions is 9.48. Hence, at the means, separability between meats and fish in Japan cannot be rejected. The elasticities of the Japanese meat expenditure share system with quasi-separability imposed between each of the meats and the fish group are presented in table 2.

Testing for Perfect Substitutability among Meats

The compensated cross-price elasticities for import-quality beef in the Wagyu beef expenditure share equation and for Wagyu beef in the import-quality beef expenditure share equation are positive but not particularly large (table 2). This suggests that Wagyu and imported beef are net substitutes but not perfect substitutes. It is relatively simple to construct an asymptotic likelihood ratio test to determine whether Wagyu and import-quality beef are, in fact, perfect substitutes. To see how this might be done, consider the results that might be expected in a model of the U.S. meat system where beef was subdivided into beef from the traditional English breeds and beef from the nontraditional breeds. Although these expenditure shares need not be similar, each would be expected to react similarly to relevant price changes if, in fact, these two beef types are perfect substitutes. Also, the prices of these two types of beef would be expected to be perfectly correlated even when the relative quantity supplied of each beef type is changed. If this were not the case, consumers would refuse to purchase the higher priced of the two beef types that they consider to be identical. This implies that producers of both beef types would receive no price signals to change the relative proportions of each beef type supplied.

Table 2. Hicksian Elasticities for Separability and Perfect Substitution Tests

Type Expenditure	Unrestricted[a]	Separability Imposed	Perfect Substitution Imposed
Chi-square		6.20	391.93*[b]
Wagyu beef			
Wagyu beef	−1.78	−1.43	[c]
IQ beef	0.23	0.26	[c]
Pork	0.98	0.47	[c]
Chicken	0.50	0.27	[c]
Fish	0.06	0.43	[c]
Expenditure	1.83	0.94	[c]
IQ beef			
Wagyu beef	0.21	0.23	[c]
IQ beef	−0.29	−0.38	−0.97
Pork	0.18	−0.06	2.18
Chicken	−0.24	−0.22	−0.65
Fish	0.13	0.43	−0.92
Expenditure	2.49	2.07	−0.05
Pork			
Wagyu beef	0.31	0.15	[c]
IQ beef	0.06	−0.02	0.76
Pork	−0.66	−0.48	−1.49
Chicken	−0.11	−0.08	0.53
Fish	0.40	0.43	−0.01
Expenditure	0.53	0.52	1.14
Chicken			
Wagyu beef	0.28	0.15	[c]
IQ beef	−0.15	−0.14	−0.41
Pork	−0.20	−0.14	0.92
Chicken	−0.42	−0.30	−0.53
Fish	0.49	0.43	0.14
Expenditure	1.60	1.83	1.02
Fish			
Wagyu beef	0.01	0.04	[c]
IQ beef	0.02	0.05	−0.10
Pork	0.13	0.14	−0.01
Chicken	0.09	0.08	0.03
Fish	−0.24	−0.31	0.10
Expenditure	0.79	0.89	1.06

Note: Homogeneity and Slutsky symmetry are imposed in all cases. IQ Beef is import-quality beef.
[a] From table 1.
[b] Asterisk indicates significant at the 1% level.
[c] The Wagyu and import-quality beef shares are combined under IQ beef for the elasticity calculations.

To test the hypothesis that Wagyu and import-quality beef are perfect substitutes, therefore, the price and expenditure coefficients in the Wagyu and import-quality beef equations were restricted to be equal. The intercept terms were not restricted. With the asymptotic likelihood ratio test, the null hypothesis of perfect substitutability of Wagyu and import-quality beef can be rejected at the 1% level of confidence. This result is of particular relevance because the Japanese government has restricted beef imports to protect the Wagyu beef industry. This policy implies that the Japanese government considers Wagyu and imported beef to be close substi-

tutes. This does not seem to be so, however. Any decrease in import-quality beef prices will influence Wagyu beef demand only through the cross-price elasticity. The elasticities with perfect substitutability imposed between Wagyu and dairy beef are presented in the last column of table 2.

The elasticities for the import-quality beef and pork shares are strongly affected by this restriction. The imposition of perfect substitutability, along with homogeneity and Slutsky symmetry, results in fourteen restrictions on the twenty-eight estimated parameters. The cumulative effect of these restrictions dramatically changes some of the estimated parameters from their unrestricted values.

This test is obviously overly restrictive and is not a test of the degree of substitutability among meats. It does, however, indicate that in Japan, in contrast to most other countries, beef from different breeds cannot be considered perfectly substitutable.

Testing for Net Substitutability among Meats

An examination of the second column of table 1 indicates that import-quality beef and pork are complementary to chicken meat. Although quite common in studies of this type, this complementarity is somewhat unsettling. It is difficult to believe that consumers would react to increases in import-quality beef prices or pork prices by consuming less chicken regardless of the culture or culinary practices. In addition, if this demand system were incorporated into a model of the Japanese livestock sector, it would lead to counterintuitive policy simulation results. In this sense, the demand system is not well behaved.

A common response to this problem is to mine the data by using alternative definitions of prices or quantities or by utilizing alternative functional forms. If this sequential pretesting did not produce the desired substitutability among meats, one could impose the desired result by specifying an appropriate functional form on the utility function. Another alternative would be to explicitly impose net substitutability econometrically by specifying that the compensated cross-price elasticities must be greater than or equal to zero. When binding, this elasticity would be zero. By imposing a priori beliefs in this manner, however, the econometric approach is a compromise that neither allows the researcher to learn from the data nor produces reasonable results. In addition, zero cross-price elasticities serve to isolate the impacts of shocks to particular commodities rather than to the entire group.

Geweke has demonstrated how inequality constraints can be imposed by means of Bayesian inference. Chalfant and White have used this approach to impose curvature restrictions on a set of substitution elasticities of a translog cost function. This section demonstrates how to test and impose net substitutability among meats for an AID system using Geweke's Bayesian approach as outlined in Chalfant and White. By treating net substitutability among meats as diffuse prior information and combining this information with the sample likelihood function by using Bayes' theorem, a posterior likelihood function that is defined only over the restricted sample space is obtained. Estimates of the elasticities can then be calculated from this posterior distribution. With a quadratic loss function, the mean value of this posterior distribution is optimal. (For an excellent discussion, see Chalfant and White.)

The procedure for finding this posterior distribution is as follows. First, the demand system is estimated with or without symmetry and homogeneity imposed. The parameter vector and covariance matrix from this procedure are then used to generate a multivariate, normal distribution. The parameter vectors from this generated distribution that satisfy net substitutability become the posterior distribution. The number of replications required depends, in part, on a priori beliefs as to the number of replications that will, in fact, satisfy the restrictions. The proportion of draws that satisfy the restrictions measures the probability that the system meets the restrictions (Chalfant and White). The mean values of this posterior distribution can then be used to calculate the elasticities, which will, by construction, satisfy net substitutability.

From the equation for computing the Hicksian elasticity (8), it is clear that, for the net substitutability restriction to be satisfied ($\delta_{ij} > 0$) at the means, γ_{ij} must be greater than $-W_j * W_i$. Therefore, to impose net substitutability at the means, the value of the cross-price parameter must be restricted to be greater than the negative of the product of the expenditure shares.

With this procedure, the Japanese meat demand system with homogeneity and symmetry imposed was estimated to obtain estimates of the coefficients and corresponding covariance matrix. These coefficients were assumed to be point values taken from a multivariate normal distribution with population variances equal to those

in the variance-covariance matrix. A sample distribution of the parameter set was then constructed by using a randomly generated, multivariate normal distribution. With use of a Monte Carlo procedure with inequality restrictions, 20,000 replications were generated. Each replication was then checked to determine if net substitutability was satisfied. The percentage of draws not violating this restriction indicates whether or not the restriction holds (Chalfant and White). The mean values of those vectors that satisfy the restrictions become the estimated parameter vector. For example, when net substitutability between all meats was imposed, the percentage of observations that satisfied the restriction was 1.13%. That is, of the 20,000 multivariate replications of the parameter set, only 226 satisfied the restrictions that all meats are net substitutes. The elasticities from the mean values of those results that satisfied the restrictions are presented in the last column of table 3.

This methodology can also be used to indicate which meat may be responsible for the replications that violate the restrictions. This is achieved by dropping the inequality restrictions for one meat at a time and then observing the change in the proportion of replications for which the substitutability restrictions are accepted while maintaining both the Slutsky symmetry and homogeneity restrictions. These results are presented in the first five columns of table 3.

The first row of table 3 indicates, for example, that 3.68% of the replications satisfied the restriction that import-quality beef, pork, chicken, and fish are substitutes. When the inequality restrictions are relaxed for one meat at a time, the

Table 3. Imposing Net Substitutability Among Meats

	Restrictions Not Imposed For					Restrictions Imposed for
	Wagyu Beef	IQ Beef[a]	Pork	Chicken	Fish	All Meats
Percent acceptance	3.68	7.65	2.86	10.35	5.86	1.13
Wagyu beef						
Wagyu beef	−1.50	−1.62	−1.81	−1.79	−1.82	−1.20
IQ beef	0.11	0.13	0.24	0.23	0.32	0.12
Pork	0.84	0.74	0.90	0.78	0.95	0.38
Chicken	0.31	0.40	0.40	0.49	0.51	0.20
Fish	0.23	0.35	0.26	0.29	0.06	0.49
Expenditure	1.67	1.47	1.45	1.50	1.95	1.16
IQ beef						
Wagyu beef	0.10	0.12	0.22	0.20	0.28	0.11
IQ beef	−1.30	−0.89	−1.05	−0.57	−1.37	−1.08
Pork	0.59	0.61	0.30	0.36	0.72	0.31
Chicken	0.32	−0.06	0.26	−0.33	0.42	0.17
Fish	0.29	0.22	0.28	0.34	−0.05	0.50
Expenditure	2.32	2.48	2.32	2.18	2.81	1.39
Pork						
Wagu beef	0.27	0.23	0.29	0.25	0.30	0.12
IQ beef	0.21	0.22	0.11	0.13	0.26	0.11
Pork	−0.83	−0.71	−0.79	−0.64	−0.86	−0.82
Chicken	0.08	0.07	−0.02	−0.04	0.09	0.10
Fish	0.26	0.20	0.41	0.30	0.21	0.48
Expenditure	0.61	0.73	0.51	0.63	0.68	0.88
Chicken						
Wagyu beef	0.17	0.22	0.23	0.28	0.29	0.11
IQ beef	0.20	−0.04	0.16	−0.21	0.26	0.11
Pork	0.14	0.12	−0.04	−0.06	0.16	0.18
Chicken	−0.81	−0.65	−0.74	−0.53	−0.91	−0.90
Fish	0.29	0.35	0.39	0.53	0.20	0.50
Expenditure	1.71	1.74	1.63	1.51	1.89	1.21
Fish						
Wagyu beef	0.02	0.04	0.03	0.03	0.01	0.05
IQ beef	0.03	0.02	0.03	0.04	−0.01	0.06
Pork	0.08	0.06	0.13	0.09	0.07	0.15
Chicken	0.05	0.06	0.07	0.10	0.04	0.09
Fish	−0.19	−0.19	−0.26	−0.26	−0.10	−0.35
Expenditure	0.78	0.73	0.85	0.84	0.64	0.94

[a] IQ beef is import-quality beef, which includes both imported beef and domestic dairy beef.

only consistent complementarity is between chicken and both import-quality beef and pork. At the same time, the percentage of replications satisfying the restrictions is highest when chicken is not restricted to being a substitute of the other meats. Although perhaps simply the result of the particular data set utilized, this finding may be related to the unique and diversified Japanese food consumption patterns and traditions. Further research on this point is warranted. It is also interesting to note that all cross-price elasticities are positive when no restrictions are placed on Wagyu beef. These elasticities satisfy net substitutability with fewer restrictions than elasticities with restrictions imposed upon all meats. Consequently, they may also be useful for policy analysis.

Concluding Comments

This paper presents tests of three hypotheses regarding meat-consumer behavior in Japan: (*a*) separability of meats and fish, (*b*) perfect substitutability of Wagyu and import-quality beef, and (*c*) net substitutability of meats. These hypotheses are central to the debate on the likely effects of liberalization of Japanese meat markets. The tests of these hypotheses are new and were developed for the LA/AIDS model of the Japanese meat demand system used in this study. The demand system is well behaved in that it satisfies the theoretical restrictions of homogeneity and Slutsky symmetry. The restrictions on the demand system implied by the hypotheses are relatively simple to estimate and can be imposed and tested by using commercially available software.

The first two restrictions (separability and perfect substitutability among meats) essentially focus on the choice of dependent variables. The test of each restriction merely formalizes the decision-making process that is implicitly performed in ad hoc models. Both restrictions are imposed without changing the number of equations in the system. This method provides a basis for comparison of likelihood functions. The first test can be used in various applications to determine whether a particular commodity should be included in a demand system. In developing models to analyze the likely effects of the increasing openness of Japanese meat markets, whether or not fish should be included in the meat demand system has been a controversial issue. The separability test developed in this paper suggests that an assumption of weak form separability between meats and fish in Japan is not an incorrect specification.

The second test examines the level of aggregation that can be used in a demand system. The test provides evidence as to whether two commodities are perfect substitutes and can, therefore, be treated unambiguously as a single commodity. Most analyses of Japanese beef markets and policies have treated domestic and imported beef as identical commodities (e.g., Anderson and Hayami). Other researchers, however, have claimed that this is an inappropriate procedure (e.g., Mori, Gorman, and Faminow). In this paper, the hypothesis that Wagyu and imported beef are perfect substitutes is rejected, implying that each type of beef must be treated as a separate commodity in analyzing the effects of Japanese beef import policies on the Japanese livestock industry.

The third restriction tested is much more practical, providing a theoretically plausible means of imposing prior beliefs about the degree of substitution between two commodities in a demand system. Typically, policy analysts are forced to ignore much of what the literature in demand theory has to offer because of the necessity of obtaining econometric results that conform to prior expectations. Ad hoc models are generally favored because they allow the analyst to search among an infinite variety of possible model specifications for the subsets of parameters that produce reasonable policy simulation results. The flexibility provided by ad hoc models, however, is also their major weakness because the properties and robustness of the presented results are unclear. Even though the flexibility of theoretically richer models is greatly limited because the functional relationships and, to a certain extent, the dependent variables to be used are specified, the results are much more robust. However, where the results of these analyses are to be used for policy analysis, otherwise trivial results, such as estimated complementarity between two meats, can be of great importance. In this paper, a Bayesian procedure to impose and test net substitutability among commodities in an AID system is used to derive elasticities for the Japanese meat demand system that, by construction, satisfy net substitutability. Although the procedure does not guarantee that all Marshallian cross-price elasticities will be positive, it does remove all negative Hicksian elasticities caused by net complementarity.

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The Determinants of the Migration of Labor out of Agriculture in the United States, 1940–85

Andrew P. Barkley

The flow of labor out of production agriculture is analyzed using a two-sector model of occupational choice. A migration equation is specified and tested empirically using aggregate data for the United States. The economic determinants of the migration of all farm workers and farm operators are established. Farm labor is found to be responsive to changes in the returns to agricultural labor relative to nonfarm labor returns. Given this responsiveness, policies intended to increase farm income will affect the level of agricultural employment.

Key words: labor migration, occupational choice, two-sector model, U.S. agricultural labor.

The quantity of labor employed in agricultural production in the United States has diminished dramatically over the past several decades; farm employment dwindled from over nine million workers in 1940 to just over three million persons in 1985 (table 1). The flow of labor out of agriculture has been studied extensively, but occupational migration at the aggregate level has not been carefully considered since the 1960s (Greenwood). Obtaining accurate and up-to-date estimates of the determinants of occupational migration is crucial for the evaluation of agricultural policies that attempt to increase farm income and stabilize farm employment.

Early studies of off-farm migration experienced difficulties in finding empirical relationships between the flow of labor out of agriculture and economic variables that were expected to influence the quantity of labor in the farm sector (Sjaastad 1961, Bishop). Econometric research led to successful estimation of the supply of and demand for farm labor (Tyrchniewicz and Schuh, Heady and Tweeten). These models illuminated conditions in the agricultural labor market at the time of the studies but did not explain migration as a decision made by rational economic agents.

The objective of this paper is to evaluate the economic determinants of the migration of labor out of production agriculture in the United States for (*a*) all farm workers and (*b*) farm operators. The paper proceeds by first examining the theoretical aspects of the occupational migration of labor out of production agriculture. This is followed by the specification of a migration equation that is then tested empirically using aggregate time-series data.

Theoretical Considerations

The decision to migrate from production agriculture is analyzed using a model of occupational choice that builds on Sjaastad's (1962) pioneering view of migration as an investment in human capital and Todaro's study of labor migration. A two-sector approach is utilized by disaggregating the economy into a production agriculture sector and a nonfarm sector that includes all other occupations (Mundlak 1988).

Consider an individual facing given returns (wages) in two mutually exclusive occupations: the production of agricultural products ($i = 1$)

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Table 1. Data Employed in Migration Study

Year	INC[a]	d	L1	M	L1S	S	LAND	GOV	U
1940	2.79	3.09	9082	0.007	5213		33.3	0.11	14.6
1941	2.47	2.46	8663	0.046	4912	0.058	36.4	0.06	9.9
1942	2.10	1.96	8806	−0.017	4359	0.113	30.8	0.05	4.7
1943	1.93	1.88	8644	0.018	4313	0.011	32.1	0.04	1.9
1944	1.94	1.94	8453	0.022	4480	−0.039	33.3	0.05	1.2
1945	1.87	1.78	8153	0.035	4448	0.007	36.7	0.05	1.9
1946	1.72	1.50	7927	0.028	4582	−0.030	33.3	0.04	3.9
1947	1.75	1.50	7890	0.005	4750	−0.037	33.3	0.02	3.6
1948	1.56	1.38	7629	0.033	4470	0.059	32.6	0.01	3.8
1949	1.86	1.74	7658	−0.004	4404	0.015	34.1	0.01	5.9
1950	1.82	1.65	7160	0.065	4146	0.059	33.3	0.01	5.3
1951	1.70	1.50	6726	0.061	3834	0.075	34.0	0.01	3.3
1952	1.83	1.56	6500	0.034	3760	0.019	38.3	0.01	3.0
1953	1.94	1.72	6260	0.037	3643	0.031	40.9	0.01	2.9
1954	1.96	1.79	6205	0.009	3648	−0.001	40.9	0.01	5.5
1955	2.19	2.09	6450	−0.039	3573	0.021	44.2	0.01	4.4
1956	2.24	2.12	6283	0.026	3405	0.047	44.2	0.03	4.1
1957	2.20	2.11	5947	0.053	3158	0.073	47.7	0.06	4.3
1958	1.94	1.78	5586	0.061	2949	0.066	47.8	0.05	6.8
1959	2.16	2.07	5565	0.004	2888	0.021	50.0	0.04	5.5
1960	1.98	1.94	5458	0.019	2675	0.074	52.2	0.03	5.5
1961	1.83	1.89	5200	0.047	2612	0.024	54.3	0.07	6.7
1962	1.79	1.88	4944	0.049	2497	0.044	55.3	0.09	5.5
1963	1.70	1.83	4687	0.052	2309	0.075	57.4	0.08	5.7
1964	1.76	1.97	4523	0.035	2207	0.044	61.7	0.11	5.2
1965	1.56	1.76	4361	0.036	2150	0.026	64.6	0.11	4.5
1966	1.49	1.63	3979	0.088	1999	0.070	66.0	0.14	3.8
1967	1.53	1.66	3844	0.034	1995	0.002	70.0	0.14	3.8
1968	1.52	1.73	3817	0.007	1985	0.005	76.0	0.15	3.6
1969	1.45	1.54	3606	0.055	1896	0.045	76.9	0.15	3.5
1970	1.42	1.46	3463	0.040	1811	0.045	77.8	0.14	4.9
1971	1.39	1.43	3394	0.020	1751	0.033	75.4	0.11	5.9
1972	1.26	1.34	3484	−0.027	1796	−0.026	77.0	0.12	5.6
1973	0.98	0.92	3470	0.004	1785	0.006	72.6	0.05	4.9
1974	1.13	1.02	3515	−0.013	1765	0.011	79.5	0.01	5.6
1975	1.05	1.06	3408	0.030	1728	0.021	82.4	0.01	8.5
1976	1.16	1.16	3331	0.023	1654	0.043	88.7	0.02	7.7
1977	1.15	1.20	3283	0.014	1586	0.041	100.0	0.04	7.1
1978	1.07	1.12	3387	−0.032	1629	−0.027	100.9	0.05	6.1
1979	1.02	1.00	3347	0.012	1603	0.016	100.0	0.02	5.8
1980	1.25	1.20	3364	−0.005	1655	−0.032	105.1	0.02	7.1
1981	1.11	1.09	3368	−0.001	1638	0.010	106.8	0.02	7.6
1982	1.28	1.19	3401	−0.010	1636	0.001	102.6	0.05	9.7
1983	1.45	1.64	3383	0.005	1563	0.045	97.4	0.16	9.6
1984		1.31	3321	0.018	1553	0.006	94.2	0.11	7.5
1985		1.36	3179	0.043	1459	0.061	84.8	0.10	7.2

Source: See text.

[a] *INC* is ratio of disposable incomes, nonag. to ag.; *d*, ratio of average products of labor, nonag. to ag.; *L1*, agricultural employment (1,000s); *M*, occupational migration of all farm workers [see equation (5)]; *L1S*, farm operator employment (1,000s); *S*, occupational migration of farm operators [see equation (5)]; *LAND*, index of real estate value per acre deflated by PPI (1977 = 100); *GOV*, government payments divided by gross farm product; and *U* is unemployment rate in total economy (%).

and nonfarm employment ($i = 2$). The choice of occupation is determined by comparing the discounted utility derived from each job over the career of the individual. A person enters the labor force at age G_0, and retires at age T. The optimization problem confronted by such a worker can be written as equation (1), where r is the rate of discount.

$$(1) \quad H_{ik} = \int_{G1}^{T} e^{-rt}\, U(X_{it}, L_{it})dt - \int_{G1}^{T} e^{-rt}[U(X_{jt}, L_{jt}) - C_{ijt}]dt,$$

where $X_{it} = q_{it}w_{it}L_{it}$, $X_{jt} = q_{jt}w_{jt}L_{jt}$.

Utility in period t is a function of both consumption in period t (X_{it}) and the hours of work spent at job i in period t (L_{it}). The movement of an economic agent from one occupation to another occurs when the expected lifetime utility derived from a potential profession rises above the lifetime utility expected in the current job, net of the disutility associated with the transfer between jobs. Occupation i is the current career (say agriculture) and j is some other occupation (say manufacturing); C_{ijt} indicates the costs of changing occupations from i to j. These costs may include both pecuniary and psychic costs. Occupational migration occurs when net utility is negative ($H_{ik} < 0$).

The flow of labor to higher wages does not take place instantaneously because of the probability, q_i, of obtaining a job in the high-wage sector (Todaro). Although the returns to labor may be higher in manufacturing than in farming, an agricultural worker currently engaged in a job search may discount the higher wage by the probability of obtaining employment in the industrial sector.

The model presented here regards the flow of labor out of production agriculture as the occupational choice of individuals. Here, the returns to labor are regarded as summary statistics. The enormous substitution of capital for labor and the low income elasticity of demand for farm products are structural parameters that are hypothesized to affect the migration of labor only through their impact on the relative returns to labor in the farm and nonfarm sectors. While the underlying cause of off-farm labor migration may be labor-saving technological change, the individual decision to change careers is influenced by the ability to earn a living in each occupation rather than the underlying structural conditions that determine the returns to labor.

Potential migrants must make an estimate of the probability of obtaining a job in the nonagricultural sector [q_j in equation (1)] to calculate H_{ik}. This probability is incorporated into the empirical model by the inclusion of macroeconomic variables, such as the unemployment rate and the relative size of the sectoral labor forces. Economic conditions within agriculture, such as government payments to farmers and land values, are also expected to affect the flow of labor out of agriculture.

The migration of individual k occurs if $H_{ik} < 0$. An index function f_{ik} is employed to separate migrants from nonmigrants.

$$(2) \quad H_{ik}f_{ik} \leq 0 \text{ where } f_{ik} = \begin{cases} 1 \text{ if } H_{ik} < 0 \text{ (migration occurs)} \\ 0 \text{ if } H_{ik} \geq 0 \text{ (migration does not occur)}. \end{cases}$$

This index function allows for the aggregation of individual migrants by the summation of f_{ik}. The gross rate of migration from occupation i to occupation j is denoted by M_{ij}.

$$(3) \quad M_{ij} = \sum_{k=1}^{z} f_{ik},$$

where z is persons employed in occupation i.

Some persons flow from nonfarm jobs to agricultural positions in a given time period. Here, M_{ji} represents persons who enter agriculture from the nonfarm economy, and M represents net migration out of agriculture:

$$(4) \quad M = M_{ij} - M_{ji}.$$

Specification of the Migration Equation

The migration equation developed below is an application of the empirical work of Mundlak (1979). Here, migration is limited to occupational migration at the aggregate level. Occupational migration is defined as the percentage change in agricultural employment (L_1) from one year ($t - 1$) to the next (t).

$$(5) \quad M = [L_{1(t-1)} - L_{1(t)}]/L_{1(t-1)}.$$

This definition of migration is an approximation to actual migration out of production agriculture; the definition considers only changes in the number of jobs in the farm sector. As such, the definition does not distinguish between retirements or actual movements to nonfarm positions. Part-time farming has become an important aspect of agricultural labor markets.

However, because of data limitations, this development is ignored here. This leads to an underestimate of the movement of labor out of agriculture; many of the persons that are counted as farm workers in this study are part-time farmers.[1]

Migration is expected to be a function of the returns to labor in the nonfarm sector relative to the returns to labor in agriculture. Let d be the ratio of nonfarm returns to agricultural returns.

$$(6) \qquad M = f(d), \quad f'(d) > 0.$$

The larger is the nonfarm sector relative to the farm sector, the greater is its capacity to absorb migrants from agriculture. Hence, the number of migrants is expected to depend on the relative size of the labor force in each sector, reflecting the probability of obtaining employment in each sector [i.e., the q_i of equation (4) is larger]. The relative size of the labor force is introduced into the migration equation (7) by defining $g = L_2/L_1$.

The rate of unemployment in the nonagricultural sector (U) is a measure of the probability of obtaining employment in the nonagricultural sector. Other variables that yield information concerning the expected returns to labor in agriculture are included in the vector z, and e is the stochastic component of the regression model.

$$(7) \qquad m = f(d)g^{\beta 2}U^{\beta 3}z^{\beta 4}e.$$

The model is specified in semilogarithmic form, as in (8).

$$(8) \qquad M = \beta 0 + \beta 1\log(d) + \beta 2\log(g) + \beta 3\log(U) + \beta 4\log(z) + V.$$

To avoid simultaneity, all of the independent variables are lagged one period; the change in agricultural employment between period $t - 1$ and period t is modeled as a function of the predetermined variables in period $t - 1$.

One component of the vector of exogenous variables (z) is the price of land. The owners of farmland receive income in the form of capital gains when land values increase. Thus, land prices are expected to influence the migration decision of farm operators who own part or all of their land. Potential migrants compare future streams of income in alternative occupations. One way to model a forward-looking migration decision is to invoke rational expectations. If well-functioning land markets exist, the value of land reflects the expected stream of all future returns to resources in agriculture.[2] The price of land contains all of the relevant information about the expected future of the agricultural sector, and thus it is an adequate representation of expectations that are formed rationally.

A measure of government payments is included as an exogenous variable in the migration equation to capture the effects of intervention in the market for farm labor. This variable is defined as the percent of farm income that results from government payments. Equation (8) is estimated using least-squares regression for both aggregate occupational migration (M) and farm operator migration (S).

Data

Two series of agricultural employment data are available in the United States, the U.S. Department of Agriculture (USDA) series and the Bureau of the Census series. The USDA series is derived from an establishment survey, while the Census series results from a household survey. The establishment survey of the USDA leads to double-counting because many agricultural workers hold more than one job simultaneously. The USDA data have been criticized for not reporting what they claim to measure, i.e., the amount of labor actually employed in agriculture in a given time period (Johnson and Nottenberg). For this reason, the Census data series was used in this study.

Some problems also exist with the Census series. The definition of the farm labor force was changed several times during the period of this analysis. These changes altered the series significantly in 1960, 1972, and 1978. Substantial increases in the farm labor force data series occurred in both 1942 and 1955. These expansions are anomalous; the USDA series shows a decrease of farm labor in both years.

The Bureau of the Census reports a rise of 226,000 workers between 1954 and 1955. Of these, 175,000 are reported to be female. However, there is no apparent reason why the number of female workers in agriculture should increase at this rate. Dummy variables were

[1] Hours of work are difficult to include in the empirical analysis because of data limitations. The USDA publishes hours of work, but the estimates are considered unreliable (Johnson and Nottenberg).

[2] Land values are used as a proxy for the returns to all resources engaged in production agriculture. See Melichar for a discussion of the relationship between land values and the returns to agricultural resources.

included in regression trials to account for definitional changes in the Census survey in 1960, 1972, and 1978 and for the unexplained increases in farm labor which occurred in 1942 and 1955. Two of the five dummy variables (*DUM*55 and *DUM*72) were statistically significant and thus were retained in the empirical model.

Two measures of the returns to labor are used in this research: (*a*) a measure of value added per worker and (*b*) data on income per capita. The first labor returns measure is the gross domestic agricultural product divided by the number of workers in the farm labor force.

Output data for both the farm and nonfarm sectors are in nominal terms. Nominal output measures capture the effects of relative price changes (the terms of trade) between agricultural and nonagricultural products.[3] Government price supports are included in the measure of farm output. Other government payments, such as deficiency payments, are not included (government payments are included as a separate regressor).

The second measure of aggregate labor returns employed is the series of disposable income per capita in agriculture as a percentage of disposable income per person in the nonfarm sector (USDA). Disposable income for both the farm and nonfarm population is calculated by deducting taxes from total income (which includes off-farm income for the farm population) in each sector. The sectoral disposable income is divided by an estimate of the farm and nonfarm populations, as opposed to the labor force in each sector which is used in the calculation of the average product ratio. The disposable income series was discontinued by the USDA in 1983, causing the ending year of the regression analyses to be different for the average product and the disposable income regressions.

The measure of land prices is the USDA series of real estate values (index, 1977 = 100), deflated by the producer price index for farm products.[4] The government intervention variable is derived by dividing the total amount of government payments to agriculture (USDA) by farm income to obtain the percent of income from government sources. The unemployment variable (Bureau of Labor Statistics) reflects unemployment in the entire economy.

Results

The regression results for total migration and farm operator migration are presented in table 2. A functional relationship is found between the relative returns to labor in agriculture and the level of occupational migration out of the farm sector. The remaining explanatory variables are all of the expected sign, excluding the government payments and unemployment variables, as explained below.

The regression coefficient of the ratio of labor returns variable ($\beta 2$) reports the responsiveness of a change in farm employment to changes in the relative return to agricultural labor. Elasticities are calculated at mean values. The elasticity of total farm migration with respect to the ratio of average products [$E(m, d)$] equals 4.50. This elasticity supports the hypothesis that the flow of labor out of agriculture responds to economic incentives. The results of the disposable income ratio trials are quite similar to the results of the regressions that utilize average products, indicating that the migration equation is robust to different measures of the nonfarm/farm returns ratio.

The regression results for variables that reflect macroeconomic conditions demonstrate the linkages between the farm and nonfarm sectors. The ratio of the nonfarm labor force to the farm labor force has a significant impact on the migration of labor out of agriculture. This ratio reflects the absorptive ability and the opportunity for employment of the nonfarm sector.

The government payments variable did not perform well. Government payments have divergent effects on the size of the labor force. Income assistance in the form of price supports and target prices are expected to slow the rate of migration out of agriculture. However, acreage set-asides accompany enrollment in the price support programs. Land diversion reduces the need for inputs which are complementary to land, resulting in an increase in the migration of labor out of agriculture. The government payments variable did not capture either of these anticipated effects of government policy on the agricultural sector. Perhaps the two effects offset each other and net to zero.

The benefits of government programs are expected to be capitalized into the value of farm-

[3] Real values would also reflect relative prices if the same inflation adjustment was used for both sets of data. However, the inflation rate of agricultural products differs from the inflation rate of nonfarm products. If the two different rates were used, the ratio would be purged of changes in relative prices.

[4] Although the returns ratio is left in nominal terms, the land price variable is deflated to capture changes in real land values only because this variable is not an intersectoral ratio.

Table 2. Labor Migration out of Agriculture, 1940–85

Dependent Variable: Migration of labor out of agriculture	Average Product Ratio (d) (1940–85)		Disposable Income Ratio (INC) (1940–83)	
	(1) Total	(2) Operators	(3) Total	(4) Operators
Intercept	0.20*	0.15	0.17	0.08
	(1.80)	(1.00)	(1.37)	(0.52)
Returns ratio	0.09***	0.10***	0.08***	0.11***
	(3.71)	(3.17)	(2.75)	(3.05)
Labor force ratio	0.09***	0.09**	0.08**	0.08*
	(3.20)	(2.30)	(2.42)	(1.97)
Real land price	−0.11**	−0.12*	−0.09*	−0.09
	(−2.57)	(−2.02)	(−1.88)	(−1.53)
Unemployment	−0.01	0.03***	−0.01	0.03***
	(−1.25)	(2.93)	(−1.03)	(2.80)
Govt payments	−0.003	−0.01	0.002	−0.002
	(0.65)	(−0.97)	(0.50)	(−0.29)
DUM55	−0.08***	−0.04	−0.08***	−0.03
	(−3.63)	(−1.20)	(−3.24)	(−1.14)
DUM72	−0.06**	−0.06**	−0.06**	−0.06**
	(−2.67)	(−2.09)	(−2.49)	(−2.05)
R^2	0.515	0.460	0.452	0.451
F	5.77***	4.50***	4.36***	4.22***
$E(m, d)$	4.50	3.34		
$E(m, inc)$			4.00	3.67

Notes: t-statistics are in parentheses. All explanatory variables are lagged once and in logarithms. See text for variable definitions. Level of significance; '***': $p \le 0.01$, '**': $p \le 0.05$, '*': $p \le 0.10$.

land (Floyd). Higher land values are found to be associated with less migration out of agriculture. The responsiveness of labor migration with respect to the price of land is large. This relationship reflects not only the technological substitution of inputs but also expectations of future returns to farming that are capitalized into the value of farmland.

Government intervention in the agricultural sector may have slowed the rate of migration from agriculture indirectly through higher land prices. However, government policies have not been successful at halting migration; farm incomes have not risen rapidly enough to keep pace with increases in nonfarm income over time, with the exception of the early 1970s.

Farm employment stabilized at around 3.4 million workers during the period from 1971 to 1983 (table 1). The regression results yield insight into the causes of this break in the trend of outmigration. The period was one of historically high relative farm returns (d) and disposable incomes (INC). The opening of international agricultural markets resulted in high expectations and high land values ($LAND$). This combination of high income levels and high expectations resulted in the retention of labor in agriculture for about a decade, but off-farm migration resumed during the "farm crisis" of the early 1980s.

Higher levels of unemployment are expected to detract potential migrants from leaving agriculture. However, the migration of farm operators increases in periods of high unemployment, holding all else constant. This unexpected result comes from high levels of both operator migration and unemployment rates in 1943. When this association is purged from the regression by excluding all periods before 1944, no relationship remains between the unemployment rate and the migration of farm operators.

Conclusions and Policy Implications

Economic growth has resulted in increasing nonfarm labor returns over the past several decades. Technological growth and rising nonfarm labor returns have been associated with decreasing agricultural employment; this is evidenced by the enormous decrease in the number of agricultural workers since 1940.

Agricultural policies have manipulated output prices in the attempt to mitigate the adverse effects of technological change on the farm sector. Output price increases result in a rightward shift in the demand curve for agricultural labor. While this strategy may partially offset the impact of technological change in the short run, the historical pattern of labor migration out of agriculture indicates that these policies have not raised output prices high enough to bring farm returns in line with nonfarm labor returns over the long run.

Farm labor is found to be mobile. Mobility is measured by the relatively high elasticities of annual changes in farm employment to changes in the relative returns to farm labor. Given a high degree of mobility, policies that attempt to raise farm income through price supports or direct payments are likely to result in lower levels of migration out of agriculture. While government payments did not influence changes in agricultural employment directly, an indirect impact may have occurred through increased land values. Land value appreciation slows the rate of labor migration out of production agriculture.

Price supports are included in the measure of relative labor return, and to the degree that value added in agriculture is increased by government programs, farm policy may have affected migration decisions over the course of this study. Macroeconomic conditions, as measured by the unemployment rate, were not associated with off-farm migration. However, the relative size of the labor force did influence off-farm migration.

This study has provided empirical evidence that (*a*) farm labor responds to economic conditions in the short run, and (*b*) the value of farmland, as a proxy for returns to resources in agriculture, is associated with the decision to migrate out of the agricultural sector. Technological change results in a leftward shift in the demand for agricultural labor. This causes either fewer workers in agriculture or lower returns to agricultural labor, or both. The responsiveness of labor to changes in labor returns determines which of these outcomes will ensue. If labor is responsive (elastic) to labor returns, then a shift in the demand for labor will manifest itself as a change in the level of agricultural employment.

The major implication of the estimated responsiveness of agricultural employment with respect to intersectoral returns is that policies intended to increase farm income through price and income support will affect both the level of farm employment and the level of farm income. For this reason, policy makers and analysts have and will experience difficulty in assessing the quantitative impact of farm policies on changes in agricultural employment and changes in farm income.

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A Nonparametric Approach to Expenditure-Constrained Profit Maximization

Rolf Färe, Shawna Grosskopf, and Hyunok Lee

A nonparametric approach to expenditure-constrained profit maximization is developed. A deterministic frontier profit function is constructed with and without expenditure constraints. Foregone profit is used as dual evidence for the existence of expenditure constraints. Individual evaluations on performance and expenditure constraints are produced. Empirical analysis is based on survey data for California rice farms. Seventeen of the eighty-two surveyed farms experience profit loss as a result of expenditure constraints.

Key words: expenditure constraint, frontier technology, nonparametric approach, profit maximization.

Recently Lee and Chambers (1986) developed a short-run expenditure constrained theory of profit maximization.[1] Their theory extends the work by Shephard on indirect production theory, and it has a natural place in the analysis of credit constraints. Such constraints occur frequently in agricultural production.

In this paper we introduce a nonparametric alternative to the Lee and Chambers model and apply it to a cross section of eighty-two California rice farms. Lee and Chambers derived a parametrically testable hypothesis of expenditure constraints using a dual framework. In our nonparametric approach, constrained and unconstrained profit frontiers are constructed, and foregone profit is evaluated as dual evidence for the existence of expenditure constraints. Specifically, a deterministic frontier profit function is constructed with and without expenditure constraints using a programming approach. In spirit, this nonparametric method is closely related to that of Farrell.[2] Hence, the important distinction between our model and the Lee and Chambers model arises from the fact that our model does not presume the optimality (constrained or unconstrained) of the observed data points. Because the effectiveness of expenditure constraints is evaluated in our approach at the frontier, any inefficiency other than that resulting from binding expenditure constraints can be readily identified and isolated from effects of expenditure constraints.

Like the Lee and Chambers approach, we can model a multiple output, multiple input technology without constructing indexes; in contrast to their approach, the approach used here imposes no prespecified functional form on the data, reducing specification error. The Lee and Chambers approach was used to determine whether farms faced binding expenditure constraints at the aggregate level; the approach here yields information on the microlevel as to the expenditure constraint hypothesis. In contrast to Lee and Chambers, technology is modeled in a frontier framework, which as a byproduct yields

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[1] See Färe and Sawyer for a discussion of two of their axioms of production, and Lee and Chambers (1988) for a reply which suggests an alternative parametric test of the expenditure constrained hypothesis.

[2] For early linear programming formulations of Farrell-type efficiency measures, see Burley; Charnes, Cooper, and Rhodes. For an overview of various extensions of the original Farrell efficiency measures, see Färe, Grosskopf, and Lovell. An alternative approach which also uses linear programming techniques; but specifies a parametric model is due to Aigner and Chu. For an overview of parametric and nonparametric approaches to efficiency measurement (including stochastic approaches), see Lovell and Schmidt.

information on the performance of individual observations.

The Nonparametric Models

Our model is specified as a series of linear programming problems which, like the nonparametric efficiency measures to which they are related, produce individual measures of performance. These allow us to identify whether an individual farm faces binding expenditure constraints and the associated loss in profits resulting from that constraint. In addition, this method yields a measure of profits lost from deviations from profit-maximizing behavior unrelated to credit constraints.

Suppose there are $k = 1, \ldots, K$ observations of inputs x^k, where $x^k = (x_1^k, \ldots, x_n^k, \ldots, x_N^k) \in R_+^N$ and outputs $u^k = (u_1^k, \ldots, u_m^k, \ldots, u_M^k) \in R_+^M$. These observations may be for the same farm over K periods or K farms in the same period or panel. A nonparametric frontier technology formed by the observations may be written as the boundary of[3]

$$(1)\quad T = \left\{ (x, u) : \sum_{k=1}^{K} z^k u_m^k \geq u_m, \quad m = 1, \ldots, M \quad \sum_{k=1}^{K} z^k x_n^k \leq x_n, \quad n = 1, \ldots, N, \quad z \in R_+^K, \quad \sum_{k=1}^{K} z^k = 1 \right\},$$

where inputs x and outputs u are defined as above, $z = (z^1, \ldots, z^k, \ldots, z^K)$, and z^k is the intensity variable for activity k. The z variables serve to form convex combinations of the observed input and output data, which is perhaps best understood with the aid of a diagram.

In figure 1, three observations of (x, u) are labeled A, B, and C. Because the intensity (z) variables sum to one, the constraints in (1) form convex combinations of the three observed points. The inequalities in the constraints yield vertical and horizontal extensions of the original points

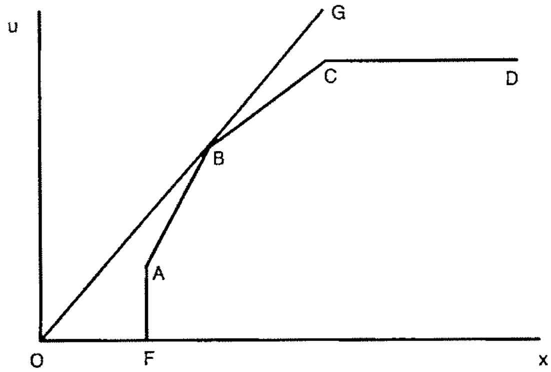

Figure 1. Frontier technology (variable and constant returns)

and their convex combinations, which allow for strong disposability of inputs and outputs.[4] The technology (1) formed by these observations is bounded by the line segments FA, AB, BC, CD, and the x-axis starting at point F.

Note that (1) allows for increasing, constant, and decreasing returns to scale. Segment AB of the technology exhibits increasing returns to scale, whereas segment BC exhibits decreasing returns to scale. If the true technology exhibits constant returns to scale, however, the restriction $\Sigma_{k=1}^{K} z^k = 1$, should be dropped. In figure 1, the new frontier technology is then bounded by OBG and the x-axis. Therefore, in the case of the variable returns-to-scale technology, point B exhibits constant returns to scale. (1) is often termed an inner approximation to the true technology, where z is the vector of intensities that shows to what extent a particular activity is employed in the production process.

To formalize the nonparametric alternative to the Lee and Chambers model, suppose that inputs can be partitioned into fixed inputs x_f and variable inputs x_v, so that each input vector $k = 1, \ldots, K$ can be written as $x^k = (x_v^k, x_f^k)$, where $x_v^k = (x_{v_1}^k, \ldots, x_{v_i}^k, \ldots, x_{v_l}^k)$ and $x_f^k = (x_{f_{l+1}}^k, \ldots, x_{f_N}^k)$. Denote output prices by $r = (r_1, \ldots, r_M) \in R_+^M$ and denote by $P_v = (P_{v_1}, \ldots, P_{v_i}, \ldots, P_{v_l})$ the price vector of variable inputs. All farms are assumed to face the same input and output prices for each output and input; therefore the k superscript is dropped for these price vectors. Short-run profit for farm k can be calculated as the solution to the linear programming problem:

[3] This technology is less restrictive than the original Farrell formulation which imposed constant returns to scale and allowed for only scaler output. Generalizations of the original Farrell piecewise linear reference technology are due to Farrell and Fieldhouse, Shephard, and Afriat, among others. A related literature provides nonparametric tests of regularity conditions in production using programming techniques, see, for example Afriat, Hanoch and Rothschild, Diewert and Parkan, and Varian for examples of this approach.

[4] (1) satisfies free disposability of inputs, i.e., if $(x, u) \in T$ and $y \geq x$, then $(y, u) \in T$, and free disposability of outputs, i.e., if $(x, u) \in T$ and $v \leq u$, then $(x, v) \in T$.

$$\text{(2)} \quad \pi_s(r, P_v, x_f^k) = \max_{u_m, x_v, z} \sum_{m=1}^{M} r_m u_m - \sum_{i=1}^{I} P_{v_i} x_{v_i}$$

s.t.

$$\sum_{k=1}^{K} z^k u_m^k \geq u_m, \quad m = 1, \ldots, M,$$

$$\sum_{k=1}^{K} z^k x_{v_i}^k \leq x_{v_i}, \quad i = 1, \ldots, I,$$

$$\sum_{k=1}^{K} z^k x_{f_i}^k \leq x_{f_i}^k, \; i = I+1, \ldots, N,$$

$$\sum_{k=1}^{K} z^k = 1, \quad z \in R_+^K.$$

In order to illustrate the programming problem in (2), consider figure 2. Suppose three observations of inputs and output are labeled A', B', and C'. The hyperplane spanned by the variable input prices and output prices is denoted by HH'. The solution to (2) is attained at C' in figure 2 (for the moment ignore EE').

Two comments on the linear programming problem (2) are in order. First, there are no constraints on the choice of the variable inputs x_v and the outputs u except the technology. Thus, this problem yields the maximal short-run profit for each observation. Second, if all inputs are variable, i.e., if $I = N$, then (2) becomes a long-run profit-maximization problem.

One of the contributions of the Lee and Chambers paper is the introduction of an expenditure constraint on the subvector of the farm's variable inputs. To introduce that type of constraint into our model, let maximum allowable expenditure be denoted as E. The corresponding

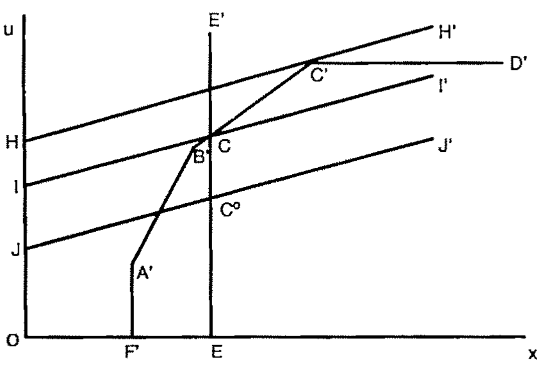

Figure 2. Expenditure-constrained profit maximization

expenditure constraint for observation k can be written as

$$\text{(3)} \qquad P_{v_1} x_{v_1}^k + \ldots + P_{v_I} x_{v_I}^k \leq E^k.$$

This constraint is illustrated in figure 2 by the area between the vertical line EE' and the output axis. From the figure it is evident that the expenditure constraint could lower profit relative to the "unconstrained" profit from (2): because the farm must choose a point like C (C' is no longer feasible), profits fall from OH to OI. Thus, if farms face binding expenditure constraints they will be losing profits.

To compute the loss in profits from the expenditure constraint, profit with the expenditure constraint (3) must be calculated. The k superscript will be dropped because the variable inputs x_v are choice variables.[5] Specifically, for farm k, expenditure constrained profit is calculated as the solution to

$$\text{(4)} \quad \pi(r, P_v, x_f^k, E^k) = \max_{u_m, x_v, z} \sum_{m=1}^{M} r_m u_m - \sum_{i=1}^{I} P_{v_i} x_{v_i}$$

s.t.

$$\sum_{k=1}^{K} z_x u_m^k \geq u_m, \quad m = 1, \ldots, M,$$

$$\sum_{k=1}^{K} z^k x_{v_i}^k \leq x_{v_i}, \quad i = 1, \ldots, I,$$

$$\sum_{k=1}^{K} z^k x_{f_i}^k \leq x_{f_i}^k, \quad i = I+1, \ldots, N,$$

$$\sum_{i=1}^{I} P_{v_i} x_{v_i} \leq E^k,$$

$$\sum_{k=1}^{K} z^k = 1, \quad z \in R_+^K.$$

A comparison of (4) and (2) shows that $\pi_s(r, P_v, x_f^k) \geq \pi(r, P_v, x_f^k, E^k)$, thus profit loss resulting from the expenditure constraint, which we call financial efficiency, can be defined as

$$\text{(5)} \qquad F^k = \pi(r, P_v, x_f^k, E^k)/\pi_s(r, P_v, x_f^k),$$

where F^k is less than or equal to one, with $F^k = 1$ if the expenditure constraint is not binding.

[5] As a practical matter the maximum allowable expenditure is calculated as observed expenditure on variable inputs, i.e., $\sum_{i=1}^{I} P_{v_i} x_{v_i}^k$ is used as a proxy for E^k.

The computation of F^k requires data on inputs, outputs, variable input prices, output prices, and expenditure. Unfortunately, the data set does not include information on quantities of inputs and outputs; rather, it includes information in value terms. Specifically, information is available on revenues, costs, and variable input expenditure. Thus, the model introduced above must be modified. We follow the basic model developed by Färe and Grosskopf.

Define the revenue associated with output m as $R_m = r_m u_m$ and the cost of variable input v_i as $C_{v_i} = P_{v_i} x_{v_i}$, and similarly for fixed inputs. The data now consist of $k = 1, \ldots, K$ observations of $R^k = (R_1^k, \ldots, R_m^k, \ldots, R_M^k)$, $C_v^k = (C_{v_1}^k, \ldots, C_{v_i}^k, \ldots, C_{v_I}^k)$, and $C_f^k = (C_{f_{I+1}}^k, \ldots, C_{f_N}^k)$. Assume that all of the farms in the sample face the same input and output prices.[6] Under this assumption, the short-run profit-maximization problem from (2) becomes

$$(6) \qquad \pi_s(C_f^k) = \max_{R_m, C_v, z} \sum_{m=1}^{M} R_m - \sum_{i=1}^{I} C_{v_i},$$

s.t.

$$\sum_{k=1}^{K} z^k R_m^k \geq R_m, \quad m = 1, \ldots, M,$$

$$\sum_{k=1}^{K} z^k C_{v_i}^k \leq C_{v_i}, \quad i = 1, \ldots, I,$$

$$\sum_{k=1}^{K} z^k C_{f_i}^k \leq C_{f_i}^k, \quad i = I+1, \ldots, N,$$

$$\sum_{k=1}^{K} z^k = 1, \quad z \in R_+^K.$$

In this modified problem, the nonparametric frontier technology is constructed from observed revenues R_m^k and observed costs $C^k = (C_v^k, C_f^k)$ rather than observed output and input quantities. To show that the two models (2) and (6) yield the same maximum under these assumptions, it is sufficient to compare their respective first constraints. From (2),

$$(7) \qquad \sum_{k=1}^{K} z^k u_m^k \geq u_m, \quad m = 1, \ldots, M.$$

The assumption that each farm faces the same prices is used to obtain

$$(8) \qquad r_m \left(\sum_{k=1}^{K} z^k u_m^k \right) \geq r_m u_m = R_m,$$

$$\sum_{k=1}^{K} z^k (r_m u_m^k) \geq R_m,$$

$$\sum_{k=1}^{K} z^k R_m^k \geq R_m.$$

This expression shows that the first constraint of problem (2) is equivalent to the same constraint of problem (6); because similar arguments can be made to show the equivalence of the rest of the constraints in each problem, we may conclude that $\pi_s(r, P_v, x_f^k) = \pi_s(C_f^k)$, given identical firm-level prices.

Following the procedure outlined above, the expenditure-constrained profit-maximization problem from (4) can be reformulated into value terms

$$(9) \qquad \pi(C_f^k, E^k) = \max_{R_m, C_v, z} \sum_{m=1}^{M} R_m - \sum_{i=1}^{I} C_{v_i}$$

s.t.

$$\sum_{k=1}^{K} z^k R_m^k \geq R_m, \quad m = 1, \ldots, M,$$

$$\sum_{k=1}^{K} z^k C_{v_i}^k \leq C_{v_i}, \quad i = 1, \ldots, I,$$

$$\sum_{k=1}^{K} z^k C_{f_i}^k \leq C_{f_i}^k, \quad i = I+1, \ldots, N,$$

$$\sum_{i=1}^{I} C_{v_i} \leq E^k,$$

$$\sum_{k=1}^{K} z^k = 1, \quad z \in R_+^K.$$

The solutions to problems (6) and (9) can be compared to obtain a measure of profit lost because of the expenditure constraint, i.e., financial efficiency,

$$(10) \qquad F^k = \pi(C_f^k, E^k) / \pi_s(C_f^k).$$

Note that $\pi(C_f^k, E^k) = \pi(r, P_v, x_f^k, E^k)$ by arguments similar to those used to prove that $\pi_s(C_f^k) = \pi_s(r, P_v, x_f^k)$. Therefore, (5) and (10) yield the same value.

Recall that the expenditure-constrained profit function is defined at the frontier technology, as

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[6] Because expenditure data are employed under this assumption, the results should be interpreted with care. For example, if pecuniary externalities exist, the results will be biased.

is clear from (4). By introducing observed profit, π^k, $k = 1, \ldots, K$, an alternative measure of performance can be obtained by comparing the values of π^k and $\pi(C_f^k, E^k)$. Thus the actual efficiency measure denoted by A^k is defined as the ratio of actual profit to expenditure-constrained profit,

$$(11) \qquad A^k = \pi^k / \pi(C_f^k, E^k).$$

By the definition of $\pi(C_f^k, E^k)$, π^k can be at most equal to $\pi(C_f^k, E^k)$, implying that A^k is always less than or equal to one in value. When farm k is actual efficient, its observed profit will equal (maximal potential) expenditure-constrained profit, i.e., $A^k = 1$. If the farm is actual inefficient, $A^k < 1$. A^k is named "actual efficiency" because $A^k = 1$ is always achievable with existing fixed inputs and the actual level of expenditure if firm k operates efficiently. Deviation of A^k from the unit value can be interpreted as a measure of profit loss by farm k as a result of actual inefficiency evaluated at the actual expenditure level.

We have examined profit loss resulting from the expenditure constraint (financial inefficiency) and profit loss caused by failure to achieve maximal potential profit given actual expenditure levels (actual inefficiency). It is intuitively clear that these two mutually exclusive measures together comprise an overall (financial and actual) efficiency measure, which can be obtained by comparing actual profit and unconstrained, maximal potential short-run profit. The overall efficiency measure denoted by O^k is defined as

$$(12) \qquad O^k = \pi^k / \pi_s(C_f^k),$$

or equivalently,

$$(13) \qquad O^k = A^k \cdot F^k.$$

Overall efficiency is decomposed into actual efficiency and financial efficiency and is expressed as the product of these two efficiency measures. This is illustrated in figure 2. A firm operating at point C^0 with observed profits OJ would have overall efficiency of OJ/OH, where C' represents optimal choice when the firm is not expenditure constrained. Financial efficiency is measured for this firm as OI/OH, where OI is the maximum achievable profit given the expenditure constraint, EE'. Actual efficiency is equal to OJ/OI, the ratio of actual to maximal expenditure constrained profit. The decomposition is confirmed since $OJ/OH = (OJ/OI)(OI/OH)$.

The decomposition above is in the spirit of the original Farrell decomposition of overall efficiency (the ratio of observed to minimal costs) into technical (price unrelated) and allocative (price related) components. It differs, however, in several ways. First, because explicit price data are not available, price related inefficiency cannot be isolated (it is effectively assumed that there is no price-related inefficiency). Second, the framework is short run: inputs are partitioned into fixed and variable inputs, where only variable inputs are choice variables. Third, performance is evaluated with respect to (variable) inputs and outputs simultaneously, whereas Farrell's original measures take output as given and effectively calculate maximum proportional feasible reductions in inputs (and associated costs).[7] Put differently, performance is measured relative to short-run profits rather than costs (or revenues). If, however, a farm is found overall efficient here, it would be maximizing revenue (given inputs and output prices) and also minimizing short-run costs (given outputs and input prices).

Data and Results

The models developed in the previous section are applied to a sample of California rice farms. These data were obtained from the 1984 national special crop survey conducted over U.S. rice producers by the U.S. Department of Agriculture. Although the original survey was conducted at a national level, this study concentrates on the California region for which the survey contains information on eighty-two individual rice-producing farms. Concentrating on one region reduces the wide variation in characteristics of rice farming at the national level. Our method presupposes that the same technology is available to all farms; thus, differences in production methods might appear as inefficiency. Because rice production techniques are fairly homogenous within the California region, this potential source of bias should be ameliorated. Focus on one region should also reduce price variation, an important consideration given our assumption that all farms face the same prices. Again, this assumption could lead to bias if pecuniary externalities exist.

[7] Under constant returns to scale, Farrell's original measures are equivalent to taking inputs as given and maximizing outputs (and revenues) (see Färe, Grosskopf, and Lovell).

Because the primary purpose of the survey was to obtain information on costs and returns in rice production, the data on individual farms are largely in value terms rather than quantities, although these values are available at a very disaggregated level. To arrive at the variable and fixed input proxy variables, the data from the survey were aggregated into three (quasi-) fixed and six variable input cost categories.

The six variable input costs included (*a*) materials, which included expenditures on fertilizer, pesticides, and custom operations;[8] (*b*) energy, which included expenditures on fuel, oil, and electricity; (*c*) leased farm equipment expenditures; (*d*) marketing services, which included transportation expenditures; (*e*) labor; and (*f*) purchased water. The proxy of E^k was calculated as the sum of these six expenditure categories for each observation. The three (quasi-) fixed input variables included (*a*) acres of land; (*b*) capital equipment in dollar value; and (*c*) overhead expenses, which included accounting fees, legal fees, insurance, taxes, and interest.

Rice farmers also produce other crops, although the survey indicated that only wheat was produced by these farmers at a significant level. Only twenty-one of the eighty-two farms produced wheat, with average revenues of $100,751. As a result, both wheat and rice revenues were included as output proxies. To compute revenues, the output measures net of seed planted were multiplied by the harvest-month price for medium- and short-grain rice and by the three-month average of winter wheat prices. Descriptive statistics of the variables are collected in table 1.

Short-run expenditure constrained profit (9) and short-run unconstrained profit (6) were calculated for each of the eighty-two farms. This involved running these two linear programming problems for each farm. The loss in profit caused by expenditure constraints was calculated as the ratio of constrained to unconstrained profit [see (10)]. The results indicate that seventeen of the eighty-two farms faced binding expenditure constraints, i.e., F^k from (10) was less than unity. The average loss for those seventeen farms was about 8% of unconstrained profits (see table 2).

Decomposition results indicate that only thirteen out of eighty-two farms are actual efficient, while sixty-five farms are financially efficient. All actual efficient farms except one exhibit financial efficiency. This fact suggests that actual efficient farms are also financially efficient (that is they are overall efficient), but financially efficient farms are not necessarily actual efficient. This observation is consistent with out intuition that, given fixed inputs, to achieve overall efficiency financial conditions must a priori allow farmers to purchase desired levels of variable inputs. However, when actual efficiency is evaluated across expenditure-constrained versus unconstrained farms, financially constrained farms perform better on average than financially unconstrained farms. An explanation for this ap-

[8] This category consisted largely of custom-hired applications of chemicals.

Table 1. California Rice Farms: 1984 Descriptive Statistics

Variable	Mean[a]	Standard Deviation
Revenues	311574.72	378545.56
Materials	85815.79	125914.60
Energy	24908.35	30310.98
Equipment	6472.65	19144.07
Marketing	28555.37	43704.82
Labor	122844.97	158193.35
Water	19093.04	32651.78
Land	511.73	661.41
Capital	284416.05	329480.66
Overhead	110133.66	236185.98

Note: Sample size: 82.
[a] All categories except land are measured in 1984 dollars, and land is measured in acres.

Table 2. Decomposition Results: Means and Frequencies

Measure	Expenditure-Constrained Farms (17 farms)	Expenditure-Unconstrained Farms (65 farms)
Actual efficiency (A^k)	0.481 (0.331)[a]	0.416 (0.390)
Number of actually efficient farms ($A^k = 1$)	1	12
Financial efficiency (F^k)	0.921 (0.128)	1.000 (0.000)
Number of financially efficient farms ($F^k = 1$)	0	65
Overall efficiency (O^k)	0.453 (0.312)	0.416 (0.390)
Number of overall efficient farms ($O^k = 1$)	0	12

[a] Numbers in parentheses are standard deviations.

parent anomaly may come from the relatively high level of quasi-fixed inputs used by the unconstrained farms. The data show that constrained farms spent on average 30% less on capital, 47% less on overhead, and had 46% less land than financially unconstrained farms. If excess capacity with respect to fixed inputs occurs for the observation period of this study, that excess capacity would more likely occur with financially unconstrained farms and could account for their comparative inefficiency.

In contrast to Lee and Chambers, the restriction that constant returns to scale prevail was not imposed. In order to determine the effect of this specification on the degree to which expenditure constraints would be binding, we recalculated the constrained and unconstrained profit-maximization problems (9) and (6) without the constraint that the intensity variables sum to unity. As mentioned earlier, dropping that restriction imposes constant returns to scale on the technology. The resulting loss in profits from expenditure constraints was similar to the variable returns case suggesting that these rice farms are relatively scale efficient.[9]

Next, we summarize additional information concerning the results on optimal variable input usage. In the single input case, input use under a binding constraint cannot be greater than the input use under no constraint. However, with more than one input, some inputs could be used more intensively with lower expenditure. Thus, examining the optimal use of variable inputs at different expenditure levels should yield insight into the underlying technology. To do so, we first select out the expenditure-constrained farms from the sample. Then the ratio of optimal variable input usage with and without expenditure constraint is calculated to compare input use between the two expenditure levels. If the resulting ratio is less than unity, then optimal expenditure constrained input usage is less than unconstrained optimal input usage and vice versa. Table 3 summarizes these results.

The results from table 3 suggest that the optimal response by farms facing binding expenditure constraints would in general be to underutilize all of their variable inputs relative to the unconstrained optimal utilization, except for marketing, which optimally would be increased relative to unconstrained levels. The most dramatic underutilization rates are for equipment

Table 3. Analysis of Constrained Farms

Variable	Mean	St. Dev.
Ratio of optimal input use with and without constraint:		
F^*	0.92	0.13
Materials	0.73	0.18
Energy	0.75	0.23
Equipment	0.32	0.33
Marketing	1.32	0.51
Labor	0.73	0.26
Water	0.86	0.21
Ratio of constrained (observed) to unconstrained expenditure:		
$E^*/E(C_f^*)$	0.78	0.18

(on average constrained rates are roughly 30% of unconstrained optimal rates). Because the equipment variable is restricted to leased equipment, this suggests that rice farmers could substitute owned equipment when faced with credit constraints. Because credit is tied to cash flow, farmers are less likely to reduce expenditures on seed, for example, than equipment. The fact that optimal expenditure on marketing is greater when farms are credit constrained is less intuitive.

These observations suggest a need to consider the validity of the model (McCarl, Gass). A possible explanation is that the variables included do not account for all farm-specific characteristics. Unlike other inputs, marketing may be especially affected by farm-specific factors (distance to market, storage capacity, etc.) which, if not accounted for, may cause systematic bias in the results.[10] One way to test model validation is to examine the dual of the problem proposed in this study (McCarl). In other words, redefine the maximization problem as its associated dual minimization problem to check for consistency of the shadow prices and programming solutions. Nevertheless, recognizing that no model reflects all of perceived reality, the nonparametric models are subject to relatively less specification error than parametric models.

Concluding Comments

In this paper we have introduced a nonparametric alternative to the expenditure (credit) constrained model of profit maximization of Lee

[9] See Färe and Grosskopf for a discussion of scale efficiency. Detailed information concerning the disaggregated results are available upon request from the authors.

[10] Because this information is not available, one way to circumvent this problem may be to use variable input expenditure excluding marketing expenses and to use the revenue figure net of marketing expenses.

and Chambers. Among pros and cons of each approach, lack of statistical properties of the current approach is offset by the ability to evaluate whether expenditure constraints are binding for individual observations.[11] Moreover, frontier specification of the profit function also produces useful byproducts, namely, observation-specific information on performance (losses in profits) caused by expenditure constraints as well as inefficiency unrelated to credit constraints.

When expenditure constraints were evaluated for individual farms, seventeen of the eighty-two California rice farms in the sample were losing profit because of expenditure constraints. The average profit loss of the expenditure-constrained farms was roughly 8% of their unconstrained profit. Given the fact that California rice farms operate on a relatively large scale, farmers in this region may have relatively easy access to credit. In light of this, further research on other rice-producing regions may provide more insight in analyzing this issue.

The findings on expenditure constraints should be interpreted with some caution. As the *Journal* editor has pointed out, there likely are other maintained behavioral hypotheses which are not incorporated here, most importantly, risk behavior. What appear to be binding expenditure constraints could reflect the prudent use of credit to limit the odds of bankruptcy should an unexpected downturn occur. Finally, the fact that constrained farms were on average more actual efficient than unconstrained farms merits further analysis, perhaps with respect to risk as suggested above.

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[11] Other advantages/disadvantages are: the parametric model estimated by Lee and Chambers is differentiable, allowing for identification of substitution possibilities, etc., and is readily estimated using aggregate time-series data but is susceptible to measurement error if the parametric form does not reflect the underlying structure of technology.

Improving on Shadow Price Information for Identifying Critical Farm Machinery

Bruce A. McCarl, D. Earl Kline, and Donald A. Bender

A method is presented for identifying critical farm machinery in a linear programming context. The method uses a technical coefficient sensitivity analysis formula that overcomes problems associated with direct use of shadow prices for critical machinery identification. Case studies show the formula identifies the benefits of altering machinery generally with less than 10% error.

Key words: farm machinery, linear programming, sensitivity analysis, shadow price, technical coefficients.

Identification of critical farm machinery bottlenecks (hereafter called critical machinery) and subsequent investigation of the net benefits obtained by adding or replacing machines is a common extension application of linear programming (McCarl et al.; Doster et al.; Krutz, Combs, and Parsons: Debertin et al.). Shadow prices play a key role in this application (Doster et al.; Krutz, Combs, and Parsons). However, shadow prices are not directly applicable because they are (*a*) indicators of the marginal effect of altering a single right-hand side, while machinery changes can alter multiple technical coefficients across multiple rows; (*b*) applicable for only a limited range of alteration; and (*c*) potentially misleading when degeneracy occurs (McCarl 1977; Paris; Gal, Kruse, and Zornig).

Fortunately, a formula which predicts the consequences of changing multiple technical coefficients is available (Mills, Freund). However, this formula is applicable to infinitesimal changes only. Further, it has not been widely applied or tested for empirical accuracy for large changes. The purposes of this article are to review the technical coefficient sensitivity analysis formula, apply this formula to machinery analysis, and report on formula reliability.

An Illustration: The Effect of Machinery Alteration

Consider a simple two-crop farm where each crop requires land preparation, planting, and harvesting. Suppose the cropping season is divided into three time periods. Both land preparation and planting can occur in the first two time periods, with land preparation preceding planting. Harvesting occurs only in the third time period. A potential linear programming (LP) formulation of this case is shown in table 1.[1] (see also table 2.) The constraints restrict the availability of land and labor in three periods, land preparation time in two periods, planting time in two planting periods, and harvest time in the harvest period. The variables reflect three timing sequences for each crop. That is, (*a*) land preparation in period 1 (*Prep*1) then planting in period 1 (*Plant*1); (*b*) land preparation in period 1 then planting in period 2; and/or (*c*) land preparation in period 2 then planting in period 2. The model also includes constraints which balance crop production and input usage with variables which depict crop sale and input purchase.

This formulation contains several simplifying assumptions regarding machinery. First, one hour

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[1] This formulation is a simplified version of the REPFARM model used in the case.

Table 1. Linear Programming Model of Simple Two-Crop Farm

	Crop Sale		Misc. Input Purchase	Plow, Plant, and Harvest Activities						
				Crop 1			Crop 2			
	Crop 1	Crop 2		Prep 1 Plant 1	Prep 1 Plant 2	Prep 2 Plant 2	Prep 1 Plant 1	Prep 1 Plant 2	Prep 2 Plant 2	
Variable	W_1	W_2	Z	X_{11}	X_{12}	X_{13}	X_{21}	X_{22}	X_{23}	
Objective function	p_1	p_2	1							Maximize
Yield balance, crop 1	1			$-y_{11}$	$-y_{12}$	$-y_{12}$				≤ 0
Yield balance, crop 2		1					$-y_{21}$	$-y_{22}$	$-y_{22}$	≤ 0
Misc. input balance			-1	d_1	d_1	d_1	d_2	d_2	d_2	≤ 0
Labor avail, period 1				$a_{11} + a_{12}$	a_{11}		$a_{21} + a_{22}$	a_{21}		$\leq t_1 * m$
Labor avail, period 2					a_{12}	$a_{11} + a_{12}$		a_{22}	$a_{21} + a_{22}$	$\leq t_2 * m$
Labor avail, period 3				$s_1 * a_{13}$	$s_1 * a_{13}$	$s_1 * a_{13}$	$s_2 * a_{23}$	$s_2 * a_{23}$	$s_2 * a_{23}$	$\leq t_3 * m$
Land prep avail, period 1				a_{11}	a_{11}		a_{21}	a_{21}		$\leq t_1$
Land prep avail, period 2						a_{11}			a_{21}	$\leq t_2$
Planting avail, period 1				a_{12}			a_{22}			$\leq t_1$
Planting avail, period 2					a_{12}	a_{12}		a_{22}	a_{22}	$\leq t_2$
Harvest avail, period 3				a_{13}	a_{13}	a_{13}	a_{23}	a_{23}	a_{23}	$\leq t_3$
Land available				1	1	1	1	1	1	$\leq n$

Note: The variables and parameters used in this model are defined in table 2.

Table 2. Summary of Nomenclature in Table 1

Variable	Description
W_i	Number of units of crop i sold
X_{ij}	Acres of crop i grown according to land preparation and planting combination j where: $j = 1$ for land preparation in period 1 and planting in period 1; $j = 2$ for land preparation in period 1 and planting in period 2; $j = 3$ for land preparation in period 2 and planting in period 2
Z	Number of dollars worth of miscellaneous inputs purchased

Parameters	Description
a_{ik}	Use of time (hours/acre) when doing operation k on crop i where: $k = 1$ depicts land preparation; $k = 2$ depicts planting; $k = 3$ depicts harvesting
d_i	Unit variable cost for growing one acre of crop i
s_i	Laborers required to harvest crop i for one hour
m	Laborers employed
n	Land available (acres)
p_i	Price of one unit of the output from crop i
t_j	Hours available in period j
y_{ij}	Yield of crop i when planted in period j

of labor is used per hour of nonharvesting machinery operation. Second, the working rates are independent of time period. Third, the working rates depend on the crop. Fourth, all jobs on the farm are combined into the preparation, planting, and harvesting categories, and all jobs within each of these categories are assumed to be done within a period for any acre.

To illustrate how changes in machinery affect the LP tableau, suppose the land preparation equipment complement is altered and the working rate changes. In turn, one would alter a_{11} and a_{21}, and twelve coefficients in the model would change. However, none of these would be right-hand sides (i.e., the items fundamentally associated with shadow prices). Further, the affected rows involve both land preparation and labor.

Machinery Alteration Value Estimation Using Shadow Prices

Traditionally, shadow prices are used to identify critical machinery in terms of those machines having the largest shadow prices (Krutz, Combs, and Parsons). In the LP model shown in table 1, high shadow prices on preparation time would signal the desirability of larger preparation equipment.

Consider the implications of an increase in the land preparation working rate where the hours spent per acre (a_{11} and a_{21}) are reduced by 20%. An estimate of the objective function consequences of this alteration involves the optimal solution variable values (x^*) as well as shadow prices from the preparation and labor rows. The value of the altering preparation working rate is the shadow prices on the two land preparation rows times by 20% of the right-hand side summed across the preparation rows.[2] In addition, the value of the labor alteration is found by multiplying the decrease in labor use (for period 1 this equals $a_{11}\, x_{11}^* + a_{11}\, x_{12}^* + a_{21}\, x_{21}^* + a_{21}\, x_{22}^*$ times 20%) times the shadow price. In general, this procedure involves (*a*) identification of the rows with altered resource usage by working rate changes (denote these as g such that some a_{gj}'s are altered); (*b*) computation of the change in resource use by the affected machinery in those rows ($\Sigma_j\, \Delta a_{gj} x_j^*$ where x_j^* is the optimal value of the jth variable and Δa_{gj} is the change in a_{gj}); and (*c*) valuing the working rate alteration by multiplying the sum from each affected row by its shadow price (u_g^*) and summing ($\Sigma_g\, u_g^*\, \Sigma_j\, \Delta a_{gj} x_j^*$).

Theoretical Justification

The preceding section gives an inferential process for computing the value of a machine working rate change. However, is this procedure accurate? The accuracy of such a procedure can be evaluated from both theoretical and empirical standpoints.

From a theoretical standpoint, this procedure is an application of a method developed by Mills in the early 1950s (Freund). This method starts from the linear programming model:

$$\text{(1)} \qquad \text{Maximize } Z = CX \quad AX \le B \quad X \ge 0,$$

[2] This assumes the model contains a row $ax = b$ which is altered so that $(.8)ax = b$. This implies the constraint will have $0.2b$ in extra resources. Thus, one can estimate the consequence by valuing a 20% increment in b. One could also take into account the reduction in a, but this is not consistent with Mills' formula.

which yields X^* as a column vector containing the optimal primal variable solution and U^* as a row vector containing the optimal shadow price solution. Now, suppose the A matrix is changed as follows:

$$A_{new} = A + \Delta A,$$

where A_{new} is the technical coefficient matrix after alteration and ΔA gives the technical coefficient changes. Mills' formula predicts that the consequent alteration in the optimal objective function for an infinitesimal ΔA is

$$(2) \qquad \Delta Z = -U^*\Delta AX^*.$$

This formula reflects multiplication of the vector of optimal shadow prices from the original model (U^*) times the matrix of anticipated changes in the A matrix (ΔA) times the vector of optimal variable values (X^*) to estimate the change in the objective function value.[3] This procedure parallels the inferential process outlined previously and may be explained in two parts. First, consider the part of the formula that involves the change in the A matrix (ΔA) times the optimal decision vector (X^*).

$$(3) \qquad \Delta R = -\Delta AX^* \text{ or } \Delta R_g = -\sum_j \Delta a_{gj}x_j^*.$$

The term ΔR is the anticipated savings in resource usage; it equals the sum of per unit resource usage change (ΔA) times the number of units of the decision variables (X^*) employed. For example, if one hundred acres ($X^* = 100$) are planted and a tenth of an hour ($\Delta A = -0.1$) is saved per acre, then one would anticipate saving ten hours in total ($\Delta R = 10$).

The change in the objective function is estimated by valuing the anticipated resource usage changes (ΔR) using the corresponding shadow prices:

$$(4) \qquad \Delta Z = -U^*\Delta R \text{ or } \Delta Z = -\sum_g U_g^*\Delta R_g = -\sum_g U_g^* \sum_j \Delta a_{gj}x_j^*.$$

Further, one may include the effect of any changes in the objective function coefficients by adding the term ΔCX^*, where ΔC is the vector of changes in the objective function. Thus, the final formula for estimation of the expected consequences of a change in the technical and objective function coefficients is

$$(6) \qquad \Delta Z = -U^*\Delta R - \Delta CX^* = -U^*\Delta AX^* - \Delta CX^*.$$

Thus, if ten hours are to be saved at a shadow price of \$5 per hour, then \$50 is the estimated value of the machinery change.[4]

This formula provides a method for estimating the effect of machinery alterations. Each machine in an LP model can be investigated to determine the effect of a 1% change in its working rate on the value of the objective function. The resultant information can then be presented along with the normal LP shadow prices. Furthermore, this method allows one to consider component machines within an operation. For example, in Purdue's Top Farmer model (McCarl et al.) or Kentucky's Kash Profits model (Jones, Debertin, and Moore), each machinery operation typically involves four or five different machines. In addition, the formula overcomes some of the shadow price limitations examining simultaneous changes in multiple rows which can overcome degeneracy problems (McCarl 1977).

Empirical Reliability

Before using formula (6) its reliability should be examined. Reliability is an issue because (6) predicts the consequences of infinitesimal ΔA, but machinery changes can cause large changes in A. In turn, changes in A alter the LP basis matrix and can have significant effects on the solution.[5]

Implementation

Formula (6) was included in the REPFARM farm planning package (McCarl 1982) used in the Purdue Top Farmer Extension program. The implementation required several steps: (*a*) the REPFARM input module was modified to identify the machinery used for each cropping operation; (*b*) a report writer module was included which calculates changes in the technical coefficient matrix and the consequent results of (6)

[3] The formula is relevant only for infinitesimal changes in the A matrix because the optimal primal and dual solution vectors are both functions of A.

[4] One could also develop information on the changes in the objective function by calculating the ΔR vector and restarting the LP solver with a parametric programming request.

[5] The basis matrix changes may involve either changes in elements or changes in the columns included. In either case the relationship between ΔA and the change in the objective value is nonlinear.

for user specified changes in the machine working rates; and (c) an additional report was added which contained the results of (6).

Empirical Reliability Testing

Formula reliability was investigated using two Texas case studies, one involving a farm in the High Plains region and the other in the Blacklands region. First, base models for each case were set up and validated. Then, the shadow prices were examined. Subsequently, the value of changes in individual machines were investigated using formula (6). The shadow prices for and results of this process for the second case study appear in tables 3 and 4. The table 3 shadow prices suggest machines in the planting operation and tractors are the likely machinery to change. However, because tractor use is a function of machinery working rates, then nonzero tractor shadow prices suggest that other machines may be desirable to change. Further, because multiple machines are used in the planting operation, then the individual machines to alter must be determined. The results in table 4 show the formula allows identification of machinery items which are implicit in shadow prices for other items (i.e., the baler value was implicit in the tractor shadow prices).

Reliability of the information generated using formula (6) was investigated for four of the higher valued machines in each case study. The working rates for the selected machines were altered individually and jointly between minus 50% and plus 100% in 5% increments as well as from 150% to 400% in 50% increments. The LP was rerun for each alteration. In turn, the predicted objective function value was calculated as follows:

$$Obj_{pred} = Obj_{base} + K^*\Delta Z, \tag{7}$$

where K represents the percentage change in the working rate, ΔZ is the result of (6) for a 1% change in the working rate, and Obj_{base} is the base model objective function value. Next, an actual objective function value (Obj_{act}) was obtained from the LP rerun. Finally, the relative error was computed as

$$\text{Error} = \frac{(Obj_{pred} - Obj_{act})}{Obj_{act}}. \tag{8}$$

Selected results from the two case farm studies are given in table 5. When one machine was changed at a time, the maximum error from the formula arose when the working rate was halved (−50%) and that error averaged 6.2%. When changes in working rates ranged from between −25% to +100%, the errors were less than 3.5%. When two machines were changed simultaneously within the 0% to +100% interval the results show a maximum average error of 2.7% with a maximum error of 7.3%. Simultaneous alterations in three machines resulted in small errors as working rates were increased from +5% to 100%. Largest errors were observed when all four machines were simultaneously changed.

These results suggest that formula (6) accurately predicts the benefits of changes in a set of machines. However, subsequent LP reruns should be conducted to verify machinery alterations selected for implementation. The results also show the formula is more accurate in upsizing versus downsizing situations. Fortunately upsizing is often of interest when identifying critical machinery in an extension context.

Table 3. Machinery Shadow Prices for Blacklands Case

Resource	Period	Value/hr. ($)
Large tractor time	Jun. 29–July 12	100.86
Large tractor time	July 13–July 26	100.86
Large tractor time	July 27–Aug. 9	100.86
Large tractor time	Aug. 10–Aug. 23	100.86
Large tractor time	Aug. 24–Sep. 6	100.86
Large tractor time	Sep. 7–Sep. 20	100.86
Large tractor time	Sep. 21–Oct. 18	100.86
Large tractor time	Oct. 19–Nov. 22	100.86
Large tractor time	Nov. 23–Dec. 27	100.86
Small tractor time	May 18–May 31	158.13
Planting time	Mar. 16–Apr. 5	70.15
Planting time	Apr. 6–Apr. 19	66.65
Planting time	Apr. 20–May 3	251.20

Table 4. Example Output: Value of 1% Increases in Machine Working Rates for Blacklands Case

Machine Changed	Value of 1% Increase ($)
Bed chopper	0.00
Cultivator	75.59
Disc	47.02
Mower/conditioner	83.88
Rake	36.77
Ripper lister	0.00
Shredder	15.56
Subsoiler	99.06
Planter	32.34
Drill	0.00
Baler	65.47
Field cultivator	17.13

Table 5. Average and Maximum Errors Arising from Formula Application

Working Rate Change	Number of Machines Being Changed at One Time: 1 Machine		2 Machines		3 Machines		4 Mach.
	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.
	(%)						
Blacklands[a]							
−50	6.20	8.97	9.01	13.22	13.21	16.81	18.07
−25	0.51	0.99	4.19	8.70	3.80	11.19	11.91
−20	0.24	0.74	2.80	5.55	2.46	7.43	7.82
−10	0.08	0.22	1.72	5.19	1.34	4.90	5.19
+5	0.02	0.05	0.91	2.97	0.90	3.24	3.39
+5	0.02	0.04	0.47	1.55	0.56	2.12	2.18
+20	0.06	0.16	0.35	0.88	0.47	1.34	1.36
+25	0.23	0.41	0.26	0.60	0.41	0.64	0.62
+50	1.46	3.78	1.29	3.57	1.46	2.65	0.20
+100	3.18	3.35	2.68	7.27	3.22	5.88	0.05
+400	5.88	15.61	4.98	14.76	5.47	11.78	0.00
High Plains[b]							
−50	7.07	9.66	18.10	45.09	68.05	109.09	233.85
−25	1.05	1.84	5.35	9.15	15.02	42.61	88.63
−20	0.66	1.40	3.33	7.05	9.16	25.83	42.55
−10	0.31	0.93	2.38	6.61	5.02	17.24	23.96
−5	0.22	0.82	1.77	4.84	3.44	12.03	15.74
+5	0.21	0.76	1.20	3.07	2.48	7.62	10.18
+20	0.35	1.15	0.88	1.85	1.58	4.44	6.64
+25	0.55	1.26	0.86	1.50	1.58	2.42	3.49
+50	0.89	1.58	0.91	2.85	1.18	2.35	1.70
+100	1.09	1.60	1.14	3.21	2.61	7.03	0.93
+400	1.46	3.06	6.10	12.92	10.76	27.62	0.00

Note: All errors are the absolute value of the difference between the predicted and actual divided by the actual.
[a] For the Blacklands case, the machines tested are the cultivator, disk, mower conditioner, and planter.
[b] For the High Plaines case, the machines tested are the shredder, planter, rotary hoe, and cultivator.

Concluding Comments

This paper reports on the utilization of Mills' formula for identifying critical machinery. Formula reliability was investigated using case examples. The predictions were generally within 5% of the results of LP runs for working rate increases of up to 100% involving up to four machines simultaneously. Formula performance worsens as more machines are simultaneously changed. This approach enhances the information contained in individual shadow prices making it more relevant to machinery alterations. The information also has been included in an expert system (Kline et al.).

Our experience suggests that this formula would aid evaluation of machinery changes and could easily be incorporated into the report writers of existing models.[6] However, the changes still need to be tested for practical consistency with reruns of the linear program, and machinery cost should be considered before selection decisions are made. Finally, the technical coefficient sensitivity analysis method could be used in other types of linear programming analyses where technical coefficients are altered.

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[6] For example, generating the estimates using the LP model in table 3 would require 12 solutions, but the formula generated the estimates from the basic solution. Similarly, the cases reported in table 5 required more than 300 runs and 24 hours of CPU time on a VAX minicomputer, but the formula generated the predictions from the base run solution data instantaneously.

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Nonparametric and Semiparametric Estimation: An Analysis of Multiproduct Returns to Scale

Giancarlo Moschini

The nonparametric and semiparametric regression models based on kernel density estimation are reviewed, and they are applied to the analysis of returns to scale in dairy farms using a multioutput cost function. Semiparametric tests of constant returns to scale and homogeneity of production are developed, and their implementation show that both of these hypotheses are rejected. Kernel estimation of the local degree of multiproduct returns to scale confirms that the sample's dairy farms are characterized by a considerable degree of scale economies.

Key words: cost function, dairy, flexible functional forms, kernel estimation, scale economies, semiparametric regression.

The functional specification of econometric models is a crucial component of applied research in agricultural economics that has been the object of considerable research. Notable is the introduction of flexible functional forms, pioneered by Diewert and by Christensen, Jorgenson, and Lau. This concept (see Barnett for a concise review) centers on the local approximation properties of a Taylor-series expansion of the unknown true function. Gallant and White, however, have exposed a number of statistical drawbacks of these local approximations, which has led to the development of models, such as Gallant's Fourier functional form, that can achieve global properties by the use of nonparametric approximations. This points the way to more general, and somewhat simpler, nonparametric estimation techniques.

The usefulness of nonparametric methods in applied analysis is underscored by Afriat's analysis of the restrictions of consistent choices. This approach has been extended to the analysis of production by Varian and by Chavas and Cox. In this paper, however, the term "nonparametric" applies to the statistical method of density estimation. Using this approach one can estimate the regression function or other functionals of interest without making any parametric assumptions about the true functional form. A parametric form can sometimes be retained for a portion of the model, and this leads to semiparametric specifications that can prove useful in hypothesis testing. Unlike the Afriat-type nonparametric methods, the nonparametric approach based on density estimation that is used in this paper has a solid statistical foundation, which is appealing for empirical applications requiring formal tests of hypotheses.

The nonparametric and semiparametric approaches to econometrics have attracted considerable interest in recent years (two general surveys are Ullah 1988b and Robinson 1988b). The purpose of this paper is to review the kernel method of nonparametric estimation and to apply this method to the analysis of multiproduct returns to scale using a cost function of Ontario dairy farms. Specific attention is devoted to the formulation of tests of interest in semiparametric form. The paper is organized as follows. The kernel density estimator of the regression function is reviewed, including a discussion of implementation procedures, statistical properties, and an introduction to the semiparametric regression. A multioutput cost function model is then presented. Two semiparametric tests are developed: a test of constant returns to scale, and a test of homogeneity of production. Finally, the kernel estimator of partial derivatives is used to obtain a measure of the local degree

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of multiproduct returns to scale in dairy farming.

Nonparametric Estimation

To introduce the nonparametric approach to estimation, consider a simple problem involving two continuous random variables Y and X, and a sample of independent realizations $\{Y_1, X_1; Y_2, X_2; \ldots; Y_N, X_N\}$ from a continuous bivariate distribution function with density $f(y, x)$. The typical problem can be formulated in terms of estimating the expectation of Y conditional on the explanatory variable X, i.e., $E(Y|X) \equiv R(X)$, where $R(X)$ can be interpreted as the regression function that underlies the model:

$$(1) \qquad Y = R(X) + U,$$

where U is an error term satisfying $E(U|X) = 0$ by construction. Usually, $R(X)$ is assumed to have a parametric form, say the linear form $R(X) = \alpha + \beta X$. Given the sample of realizations of the variables Y and X, one can estimate the parameters involved, thereby estimating the conditional expectation $R(X)$. Alternatively, one may note that the conditional expectation of Y given $X = x$ is

$$(2) \qquad E(Y|X = x) = \int_{-\infty}^{\infty} y \frac{f(y, x)}{g(x)} dy,$$

where $g(x) = \int f(y, x)dy$ is the marginal density of X. The nonparametric approach utilizes (2) to estimate $E(Y|X = x) \equiv R(x)$ by approximating the unknown density functions $f(y, x)$ and $g(x)$ given the sample of realizations of the random variables Y and X.

Silverman discusses the use of nonparametric methods for the estimation of density functions. Consider first the estimation of the univariate marginal density $g(x)$ using the sample of independently drawn realizations $X_1, \ldots, X_n$. From the definition of a probability density function, we have

$$(3) \qquad g(x) = \lim_{h \to 0} h^{-1} \Pr(x - \tfrac{1}{2}h < X < x + \tfrac{1}{2}h).$$

Because a sample-based estimate of the probability Pr(.) is given by the fraction of the sample falling in the interval $(x - \frac{1}{2}h, x + \frac{1}{2}h)$, we can choose a "small" number h and define the (naive) estimator $\tilde{g}(x)$ of the density function as

$$(4) \qquad \tilde{g}(x) = (Nh)^{-1} \sum_{n=1}^{N} I[(x - X_n)/h],$$

where $I[.]$ is an indicator function satisfying $I[w] = 1$ if $-1/2 < w < 1/2$ for $w \equiv (x - X_n)/h$, and $I[w] = 0$ otherwise. Thus, the estimator $\tilde{g}(x)$ is essentially based on the histogram constructed on the interval $x \pm \frac{1}{2}h$, where h is the window width. A significant deficiency of this estimator is that it is not smooth. Also, where the data are sparse, $\tilde{g}(x)$ could be assigned the value zero, which may be contrary to prior beliefs about the true density. The kernel estimator, introduced by Rosenblatt, overcomes these problems. This estimator is obtained by substituting a kernel function $k(w)$ for the indicator function in (4), that is,

$$(5) \qquad \hat{g}(x) = (Nh)^{-1} \sum_{n=1}^{N} k[(x - X_n)/h],$$

where the kernel function $k(w)$ typically is itself a symmetric density function, i.e., satisfying $k(w) \geq 0$, $\int k(w)dw = 1$, and $\int wk(w)dw = 0$.[1]

The kernel density estimator can be extended to the multivariate case. For instance, the joint density $f(y, x)$ is estimated by

$$(6) \qquad \hat{f}(y, x) = (Nh^2)^{-1} \sum_{n=1}^{N} k_2[(y - Y_n)/h, (x - X_n)/h],$$

where $k_2(w', w)$ is a bivariate kernel satisfying $k(w) = \int k_2(w', w)dw'$ for $w' \equiv (y - Y_n)/h$.

From (2), the kernel estimator of the regression function is obtained as

$$(7) \qquad \hat{R}(x) = \int_{-\infty}^{\infty} y \frac{\hat{f}(y, x)}{\hat{g}(x)} dy.$$

In practice it is not necessary to estimate the individual densities in (7). Using the estimators in (5) and (6) one obtains

$$(8) \qquad \hat{R}(x) = \frac{\sum_{n=1}^{N} \int y\, k_2[(y - Y_n)/h, (x - X_n)/h]\, dy}{h \sum_{l=1}^{N} k[(x - X_l)/h]},$$

or, because of the transformations $w \equiv (x - X_n)/h$ and $w' \equiv (y - Y_n)/h$,

[1] This guarantees that the estimated density is non-negative and integrates to one.

(9)
$$\hat{R}(x) = \frac{\sum_{n=1}^{N} \int (Y_n + hw')\, k_2(w', w) h\, dw'}{h \sum_{i=1}^{N} k[(x - X_i)/h]}.$$

After evaluating the integral, and noting that $\int w' k_2(w', w) dw' = 0$ for symmetric kernels, the estimated conditional mean can be rewritten as

(10) $$\hat{R}(x) = \sum_{n=1}^{N} Y_n r_n(x),$$

where

(11) $$r_n(x) = \frac{k[(x - X_n)/h]}{\sum_{i=1}^{N} k[(x - X_i)/h]}.$$

Thus, the estimator $\hat{R}(x)$ is a weighted average of the Y_n's, where the weights r_n's are sample-specific and depend on the evaluation point x, assigning the greatest weights to the observations that are closest to the evaluation point.

This regression estimator can be extended to the general case of many X variables. In the notation above, simply reinterpret x, X_n, and w as vectors of dimension M, where M is the number of X variables, and substitute $K(w)$ for $k(w)$, where $K(w)$ is a multivariate kernel function.

Sometimes the estimation of the conditional mean, or regression function, is the main point of interest of applied research, and the above will suffice. Often, however, one is interested in the derivatives of the regression function, which is typically the case if one focuses on elasticities. An obvious estimator for these derivatives is given by $\beta_j(x) \equiv \partial\hat{R}(x)/\partial x_j$. Vinod and Ullah estimate $\beta_j(x)$ using analytic derivatives of (10), whereas Rilstone and Ullah suggest the numerical derivative:

(12) $$\hat{\beta}_j(x) = [\hat{R}(x + \tfrac{1}{2}h) - \hat{R}(x - \tfrac{1}{2}h)]/h$$

where $(x + \frac{1}{2}h) = (x_1, \ldots, x_{j-1}, x_j + \frac{1}{2}h, x_{j+1}, \ldots, x_M)$, and $(x - \frac{1}{2}h)$ is similarly defined.

Implementing the Kernel Estimator

The implementation of the nonparametric estimators of the regression function and of the partial derivatives is essentially based on equation (10). This shows that $\hat{R}(x)$ is a weighted average of the Y_n's, with weights depending on the X_n's and on the evaluation point x, and as such relatively straightforward to compute. Two main choices are necessary at this stage. First, one must choose a kernel function $K(w)$. The choice of the kernel has been shown not to be crucial (Epanechnikov). A common practice is to use the multinormal density $K(w) = \Pi_{j=1}^{M} k(w_j)$, where

(13) $$k(w_j) = (2\pi)^{-1/2} \exp(-1/2w_j^2).$$

To accelerate the asymptotic bias reduction, Robinson (1988a) suggests the use of higher-order kernels, which can be constructed by linear combinations of (13), with the weights chosen such that the kernel has zero moments up to the desired order (see also Hong and Pagan).

The choice of the window width h, on the other hand, is much more important because h controls the amount of smoothing imposed on the data. Criteria that can be used range from trial-and-error with subjective choice to a variety of automatic selection methods (Marron). The point to notice is that the variance on the kernel estimator is inversely related to h, while the bias varies directly with h. Thus, if h is too large, the shape of the underlying density function is obscured (causing bias); while, if h is too small, spurious detail is introduced (causing imprecision). A viable trade-off, advocated by Ullah (1988b) and Bierens, consists in choosing

(14) $$h = c\, N^{-[1/(4+M)]},$$

where c is a proportionality constant, N is the sample size, and M is the number of nonparametric regressors involved. As in Hong and Pagan, in the empirical application that follows (14) is used and a different proportionality constant for each variable is defined, setting c_j equal to the sample standard deviation of the jth X variable.[2]

Statistical Properties

The statistical properties of the kernel estimator have been analyzed extensively; the main results are reviewed in Bierens, Prakasa Rao, and Ullah (1988b). Under certain assumptions, a crucial one being that $h \rightarrow 0$ and $Nh^M \rightarrow \infty$ as

[2] This is important to account for the possible different scale of the regressors. The procedure adopted is equivalent to putting $c =$ 1 and linearly transforming the data to have unit covariance matrix prior to the nonparametric estimation.

$N \to \infty$,[3] it is shown that the estimator $\hat{R}(x)$ is consistent and asymptotically normal, and a similar property is established for $\hat{\beta}(x)$. In particular, the variance of $\hat{\beta}_j(x)$ can be estimated by (Ullah 1988a):

$$(15) \quad V(\hat{\beta}_j) = \hat{V}(x)[Nh^{M+2}\hat{g}(x)]^{-1} \int (K')^2 \, dw,$$

where $\hat{g}(x)$ is given by (5), $K' = \partial K(w)/\partial w_j$, and $\hat{V}(x)$ estimates the conditional variance of Y given $X = x$ as

$$(16) \qquad \hat{V}(x) = \sum_{n=1}^{N} Y_n^2 r_n(x) - \hat{R}(x)^2.$$

It should be noted, however, that the rate of convergence of the nonparametric estimators is slower than the root-N rate of parametric models. The maximal rate of convergence in distribution of the kernel estimator is $(Nh^M)^{1/2}$ for the conditional mean and $(Nh^{M+2})^{1/2}$ for the response coefficients. These rates are slower than $N^{1/2}$ because of the requirement $h \to 0$ as $N \to \infty$. This feature is common to other nonparametric estimators. For example, Gallant's Fourier functional form typically does not achieve root-N consistency. When h is chosen as in (14), it is also clear that the rate of convergence of the kernel estimator is inversely related to the number of explanatory variables (the "curse of dimensionality"). For practical applications this means that large samples should be used, and that reliance on asymptotic properties for hypothesis testing may not always be appropriate. The semiparametric model can overcome the inefficiency of the nonparametric estimators and may be more useful when the main objective is hypothesis testing.

Semiparametric Regression

In the semiparametric regression model of Robinson (1988a), an unknown nonlinear form is postulated only for part of the model, which can be estimated nonparametrically, while the remaining part of the model is linear (or, more generally, parametric). Let the Z denote the variables that enter the model linearly, and X denote the remaining variables. In this case the model of interest is written as

$$(17) \qquad Y = Z\gamma + \theta(X) + U,$$

where $E(U|Z, X) = 0$. Because of the generality of $\theta(X)$, the identification conditions for this model preclude Z from having an intercept, and require that no element of Z be included in X.

In this context, interest usually centers on the estimation of γ. If $E(Z|X)$ is a well-defined operation, from (17) we can write

$$(18) \quad Y - E(Y|X) = [Z - E(Z|X)]\gamma + U.$$

The conditional expectations $E(Y|X)$ and $E(Z|X)$ in (18) can be evaluated without making unduly restrictive assumptions about $\theta(X)$ utilizing the nonparametric regression estimator described above. Given this, γ can be estimated by a no-intercept ordinary least squares (OLS). Robinson (1988a) shows that the estimator of γ obtained in this fashion achieves root-N consistency and asymptotic normality. As will be shown below, some hypotheses typically of interest in production economics can be cast in a form such as (17), thereby providing an efficient test without making any restrictive assumption about the function being estimated.

A Cost Function Model for Dairy Farms

Because the nonparametric methods described above expand on the notion of flexibility that has been the tenant of many empirical applications, they offer a new approach to typical estimation and testing problems in production economics. In this paper a multiproduct cost function of Ontario dairy farms is analyzed using a large body of farm-level data. The relatively large number of observations offers a credible application for the nonparametric estimation approach, in view of the caveats on the slow rate of convergence discussed earlier. The predominantly cross-section nature of the data means that the estimated model is more suitable for studying the long-run structure of the typical farm. The analysis focuses on the issue of scale economies, which has important implications for the long-run configuration of the dairy industry in Canada.

For the problem at hand, the optimization behavior of the farms is best described conditional on the output level, which leads to a cost function representation of the production structure. More formally, if the production technology is described by the production possibilities set T, which contains all the combinations (Q, q) of output vectors Q and input vectors q that are

[3] For example, in the univariate case this means that the window width must get smaller as N increases, but at a rate lower than N^{-1}. This guarantees that the expected number of sample points in the interval $x \pm \frac{1}{2}h$ tends to infinity as $N \to \infty$.

technically feasible, given a vector $\tilde{p}$ of nominal input prices, the cost function $\tilde{C} = C(Q, \tilde{p})$, defined as

$$(19) \qquad C(Q, \tilde{p}) \equiv \min_{q} \{\tilde{p}q : (Q, q) \in T\},$$

provides a dual representation of this technology. Under some general conditions, $C(Q, \tilde{p})$ is a continuous, nonnegative, nondecreasing function, positively linearly homogenous and concave in $\tilde{p}$ (McFadden).[4] The property of homogeneity in prices is maintained by expressing deflated costs $C \equiv \tilde{C}/\tilde{p}_1$ in terms of a vector of deflated prices $p \equiv \{1, \tilde{p}_2/\tilde{p}_1, \ldots, \tilde{p}_t/\tilde{p}_1\}$, where t is the number of inputs and the deflator is one of the prices (the first one in this case) such that $C = C(Q, p)$.

This cost function is estimated using a data set consisting of 612 farm-level observations of Ontario dairy farms spread over the six years from 1978 to 1983. Inputs are aggregated into four groups: labor, feed, other intermediate inputs, and capital, and for each group a Fisher price index was constructed. The production vector consists of three output groups: milk, livestock products, and crops. Milk output is measured in hectoliters of 3.6% fat content milk, while the other two outputs represent a collection of products aggregated via a Fisher index. All right-hand-side variables are normalized to equal 1 at the median value of the sample, and the total cost of production is measured in dollars. More details on the nature of the data, and on aggregation procedures, can be found in Moschini.

Semiparametric Test of Constant Returns to Scale

The hypothesis of constant returns to scale in production represents an important benchmark. It implies that input proportions are independent of the scale of production and are determined only by the relative price of the inputs. This has important implications for the impact on input demand of supply management and other policies that may affect output at the farm level. Also, constant returns to scale justify the use of linear programming models of the farm firm, a widespread tool of farm management analysis.

Constant returns to scale are best understood in the context of homogenous production structures. Lau generalized this case to the multiproduct case and defined the notion of almost homogeneity. According to this characterization, the production structure is almost homogenous of degree 1 and s if $(Q, q) \in T$ implies $(\lambda^s Q, \lambda q) \in T$ for $\lambda > 0$ (when all inputs are scaled by the same proportion λ, all outputs are scaled by λ^s). In this case, the multiproduct cost function is homogenous of degree $\alpha = 1/s$ in outputs (Brown, Caves, and Christensen). When $s = \alpha = 1$, we have constant returns to scale, and the cost function can be written as

$$(20) \qquad C = Q_1 C(\bar{Q}, p),$$

where $\bar{Q} \equiv \{1, Q_2/Q_1, Q_3/Q_1\}$. Thus, (20) constitutes the model of the null hypothesis. For the alternative model it is convenient to consider the class of cost functions homogenous of degree α possibly different from one, which can be represented as

$$(21) \qquad C = Q_1^{\alpha} C(\bar{Q}, p).$$

The fact that the alternative model is not the most general one does not detract from the usefulness of the test. As emphasized by Davidson and MacKinnon, what is important is that the alternative model provides the appropriate "regression direction" and not necessarily the model of choice were the null hypothesis to be rejected. Moreover, under the null hypothesis $H_0: \alpha = 1$, the model provides the most general flexible form, so that no misspecification error from that source is likely to emerge.

Taking logs of both sides of (21) yields

$$(22) \qquad \ln C = \alpha \ln Q_1 + \ln C(\bar{Q}, p).$$

The stochastic version of (22) has the structural form of the semiparametric model (17), with $\ln C \equiv Y$, $\ln Q_1 \equiv Z$, and $\ln C(\bar{Q}, p) \equiv \theta(X)$. Thus, using (22) the hypothesis of constant returns to scale can be tested without making arbitrary assumptions on the shape of the true cost function.

The coefficient α was estimated by the nonparametric regression framework, and the result is reported in table 1.[5] Two models were used,

Table 1. Tests of Constant Returns to Scale

Kernel	$\hat{\alpha}$	Standard Error	t-Ratio $H_0: \alpha = 1$
Standard normal	0.7644	0.0132	−17.92
Higher-order	0.7642	0.0129	−18.21

[4] Also, $C(Q, \tilde{p})$ is assumed twice continuously differentiable.

[5] Estimation was carried out on an IBM computer using user written programs coded in Fortran.

one using the normal kernel in (13) and the other using one of the higher-order kernels suggested by Robinson (1988b) (the fourth-order kernel based on (13) such that the first two moments of the kernel are both zero). In both cases, the hypothesis of constant returns to scale, $H_0: \alpha = 1$, is rejected at the 5% probability level.

Because α is the reciprocal of the degree of homogeneity of the production structure, it can itself be interpreted as a measure of returns to scale.[6] The fact that $\hat{\alpha} < 1$ suggests that milk production is characterized by increasing returns to scale.

Semiparametric Test of Homogeneity

Interpreting $\hat{\alpha}$ in the previous section as the degree of multioutput scale economies may be inappropriate in that this is strictly valid only if the underlying technology is indeed homogenous of some degree. To gain some insight into this issue, it is useful to consider other implications of the class of homogeneous production processes.

As with constant returns to scale, when the production structure is homogenous input proportions still are independent of the scale of production. This property is best expressed in terms of share equations. If $q_j(Q, p)$ represents the input level that solves the cost-minimization problem, then $S_j = p_j q_j(Q, p)/C$ gives the optimal cost share of the jth input, and from the derivative property $S_j = \partial \ln C/\partial \ln p_j$. If the cost function is homogenous in output, it can be written as $C = Q_1^{\alpha} C(\bar{Q}, p)$. In this case $\partial \ln C/\partial \ln p_j$ is independent of the output deflator Q_1, and we can write $S_j \equiv S_j(\bar{Q}, p)$. Thus, homogeneity in output implies that the optimal shares are independent of the scale of production.

This proposition can be tested by augmenting the share equations under homogeneity in the variable addition framework advocated by Pagan. A simple way of doing so is to write the share equations as

$$S_j = \delta_j Q_1 + S_j(\bar{Q}, p), \tag{23}$$

where the linear term $\delta_j Q_1$ allows for nonhomogenous departures in a useful regression direction, that is, one in which the scale of production does influence the input shares.

The stochastic version of (23) again takes the form of the semiparametric model (17). The null hypothesis of homogeneity requires $H_0: \delta_j = 0$, and under the null the model has the most flexible specification. Table 2 reports the estimated δ coefficients for the four input cost shares. Similar to the results in table 1, no differences due to the higher-order kernels were found, and only the results obtained from the standard normal kernel (13) are reported. In all cases the estimated δ are significantly different from zero at the 5% probability level, which leads to the conclusion that the technology of milk production is not homogenous.

The coefficients reported in table 2 also provide some insight into the scale bias in input demand. When all outputs are expanded in the same proportion, such that $\bar{Q}$ does not change but Q_1 increases, the share of labor is significantly decreased. On the other hand, the share of the other three inputs increases, especially those of intermediate inputs and capital. This is consistent with the observation that cost-reducing technologies in larger-scale dairy farming typically include labor-saving solutions such as milking parlors and automatic feeding techniques. This also suggests that results on the bias of technological change from aggregate data sets ought to be interpreted carefully because scale changes are usually obscured at the aggregate level when the industry output is relatively constant and the number of firms is declining, which is the case of the Ontario dairy industry.[7]

Nonparametric Estimation of Returns to Scale

The analysis in the previous sections showed that the cost function of Ontario dairy farms is likely

Table 2. Tests of Homogeneity

Cost Share	$\hat{\delta}_j$	Standard Error	t-Ratio $H_0: \delta_j = 0$
Labor	−0.0484	0.0039	−12.35
Feed	0.0094	0.0047	1.99
Intermediate Inputs	0.0273	0.0033	8.24
Capital	0.0117	0.0044	2.67

[6] The (local) degree of homogeneity of the production structure is usually taken as the measure of multiproduct scale economies (Panzar and Willig), while the (local) degree of homogeneity in output of the cost function is usually taken as measuring returns to size. However, at cost-minimizing points, the two measures are fully equivalent in that one is the reciprocal of the other. Because of this, for simplicity and uniformity of exposition here and in the rest of the paper, returns to scale are cited even though, strictly speaking, returns to size are being measured.

[7] This result also vindicates the contention that the alternative model need not be the most general one, as long as it explores a useful regression direction. The alternative of an homogenous structure allowed rejection of constant returns to scale, even though it is itself rejected in this section.

characterized by increasing returns to scale. Because the hypothesis of homogeneity is rejected, however, the coefficient of the semiparametric model (23) cannot be interpreted as the (constant) measure of the actual degree of scale economies. To obtain a measure of this parameter for the general cost function model, we can make use of the nonparametric estimator of partial derivatives of equation (12). Without loss of generality, the nonhomogenous cost function is rewritten with arguments in logarithmic form, i.e.:[8]

(24) $$\ln C = \phi(\ln Q, \ln p).$$

In keeping with the previous sections the local degree of homogeneity in output of the cost function is used as a measure of multiproduct returns to scale, that is $\rho = \Sigma_i \, \partial \ln C / \partial \ln Q_i = \Sigma_i \, \partial \phi / \partial \ln Q_i$. Thus, the degree of returns to scale involves a summation of first derivatives of $\phi(.)$, which can be estimated without any restrictive functional form assumptions by using the estimator (12).

This estimation was performed with the explanatory variables evaluated at the median point for the input prices, and at the 50%, 75%, 90%, and 95% points of the percentile distribution of output.[9] Only the normal kernel was used, and the results are reported in table 3. Significant increasing returns to scale are found for all the evaluation points. Thus, not even the largest Ontario dairy farms seem to have exploited the existing scale economies in milk production. This conclusion is consistent with the observation that the largest farms in this industry are typically smaller than in comparable U.S. situations, and with previous findings on the U.S. dairy industry (Matulich).[10] Note that Moschini had found locally constant returns to scale for the largest Ontario dairy farms. This difference in results is probably caused by the restrictiveness of the second-order approximation nature of the functional form used in that study (a hybrid-translog form), which underscores the desirability of the nonparametric approach.

Concluding Comments

The nonparametric kernel regression provides a way of estimating production relationships without making prior assumptions about the true shape of the function being estimated. As such, it provides an alternative to parametric flexible functional forms for econometric applications. Unlike other nonparametric methods used to study production technologies, the nonparametric and semiparametric models of this paper have a solid statistical foundation and permit hypothesis testing in a standard sense.

The application to estimating the cost function of Ontario dairy farms emphasized the derivations of simple tests of hypothesis in semiparametric form which, under the null, do not impose undue restrictions on the shape of the underlying technology. The results indicate that constant returns to scale and homogeneity of production cannot be maintained, and that the sample's dairy farms are characterized by substantial scale economies.

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Table 3. Estimated Returns to Scale

Percentile Evaluation Point	$\hat{\rho}$	Standard Error	t-Ratio $H_0: \rho = 1$
50	0.5489	0.0594	−7.59
75	0.6156	0.0696	−5.52
90	0.6928	0.1033	−2.97
95	0.7096	0.1352	−2.15

[8] Expressing the model in terms of logarithmic variables will change the shape of the joint density of (C, Q, p), but is inconsequential in our case because of the amorphous nature of the nonparametric estimator.

[9] Because the measure of multiproduct returns to scale used is best interpreted as relating to the slope of ray average costs (Baumol, Panzar, and Willig), the evaluation point of all three outputs is the index of milk (the most important output in this case) at the given percentile levels.

[10] For example, the 95% point of the percentile distribution of milk output for the sample used corresponds to a dairy herd of approximately 100 cows.

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A Comparison of Alternative Crop Response Models

Michael D. Frank, Bruce R. Beattie, and Mary E. Embleton

Three parsimonious models are hypothesized to represent corn yield response to nitrogen and phosphorus. Each model imposes specific restrictions with regard to the elasticity of factor substitution and growth plateau. Nonnested hypothesis tests are used to evaluate the competing hypotheses. The results support the restrictions imposed by the Mitscherlich-Baule model. For these data, corn response is characterized by limited substitution between nitrogen and phosphorus and a growth plateau. Further, the cost of using optimal input levels implied by the Mitscherlich-Baule if it were not "true" is small relative to the other parsimonious forms and a translog approximation.

Key words: crop response, elasticity of factor substitution, growth plateau, nonnested hypotheses.

Agricultural economists have been interested in the specification and estimation of agronomic response functions for some time. Notable studies include Heady, Heady and Dillon, Heady and Hexem, Johnson, Perrin and Spillman. Such studies empirically investigated the characteristics imposed a priori by the functional form selected. Recently, interest has focused on a more formal evaluation of the implicit restrictions imposed by certain commonly used models. In particular, Ackello-Ogutu, Paris, and Williams (APW) in this *Journal* and Grimm, Paris, and Williams (GPW) empirically tested certain technical aspects of crop response using nontested hypothesis tests.

Both APW and GPW found that a response model based on a von Liebig function was seldom rejected in favor of a polynomial. In the latter study, the von Liebig was compared to three commonly used polynomial functions (quadratic, three-halves, and square root) for five independent data sets. Their results support a growth plateau and zero elasticity of factor substitution (σ) between water and nitrogen (right-angle isoquants). Such characteristics follow from von Liebig's "law of the minimum." These papers (APW and GPW) as well as Paris and Knapp make a strong appeal for the von Liebig model on theoretical and empirical grounds for modeling crop response to macronutrients.

The difficulty with the results of Paris and coworkers is that it is not possible to "disentangle" the separate issues of plateau growth and factor substitution. By limiting their model comparisons to the quadratic, three-halves, and/or square root versus the von Liebig, the choice was effectively limited to plateau growth and no factor substitution or nonplateau growth and substitution. The interesting possibility of plateau growth and factor substitution was precluded given the models selected for comparison.

As a practical matter, GPW found that optimal nitrogen and water levels for corn and other crops varied substantially between alternative specifications. In particular, optimal nitrogen applications implied by simple polynomials were from 12.4% to 81.4% greater than those derived from a von Liebig function. Recommendations based on an "incorrect" model could have a substantial impact on profitability, i.e., the cost of using a misspecified model could be substantial.

This paper extends previous work by comparing the quadratic and the von Liebig to a third alternative—the Mitscherlich-Baule function. Each function is relatively parsimonious and imposes certain technical characteristics on the response curve. In particular, the Mitscherlich-Baule allows for plateau growth and factor substitution ($\sigma > 0$). Thus, the function does not

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adhere strictly to the "law of the minimum" but (unlike a polynomial) can exhibit a growth plateau. Such comparison gives more detail and flexibility regarding technical properties embodied in alternative plant growth processes. Further, by comparing the level of profit implied by each parsimonious form to that implied by a more complicated "translog" approximation, an estimate of the cost of parsimony (and the implied technical properties) is also demonstrated.[1]

The remainder of this paper is organized as follows. First, the empirical models and methodology are briefly discussed. The general problem of testing nonnested hypotheses is not discussed because the application of such methodology has become common in the literature (Ackello-Ogutu, Paris, and Williams; Grimm, Paris, and Williams; Smith, van Ravenswaay, and Thompson; Wohlgenant and Mullen). Next, the empirical results are presented and discussed. The final sections include a discussion of the relative costs of using the three parsimonious forms and a brief summary.

Empirical Models and Methodology

Determining the technical properties of plant response is largely an empirical issue. Two important aspects are elasticity of substitution and a growth plateau. Specific hypotheses regarding both are often imposed by the algebraic form of the response function.

Historically, polynomial functions (in particular, the quadratic) have been popular specifications for estimating crop response to macronutrients. The quadratic function,

$$(1)\quad Y_i = \beta_0 + \beta_1 N_i + \beta_2 P_i + \beta_3 N_i^2 + \beta_4 P_i^2 + \beta_5 N_i P_i,$$

where y_i is corn yield (bu.), N_i is applied nitrogen (lbs.), P_i is applied phosphorous (lbs.) and the β_j are parameters, imposes $\sigma \neq 0$ and no growth plateau. That is, for β_1, $\beta_2 > 0$, and β_3, $\beta_4 < 0$ yield decreases as N_i and P_i levels become large *ceteris paribus*, so that the function exhibits diminishing marginal productivity and input substitution for all N_i and $P_i > 0$. These properties plus the fact that the function is linear in all parameters contributed to its historical popularity.

In contrast, a von Liebig function,

$$(2)\quad Y_i = \min(Y^*, \beta_1 + \beta_2 N_i, \beta_3 + \beta_4 P_i),$$

where Y^* is maximum corn yield, is consistent with the idea that nitrogen and phosphorus perform different biochemical functions in plant growth (Wild). Further, the function implies that the plant responds (in a linear fashion) only to the most limiting nutrient. After some level of application (say, N^* and P^*) the plant will no longer respond to the applied nutrients. At this point, the plant reaches maximum growth (yield) at Y^*. In this manner, the specification of a von Liebig a priori imposes both $\sigma = 0$ for all levels of inputs and a growth plateau after N^* and P^*.

It seems entirely plausible, given the broad range of plant nutrients (including water) and application/availability levels, that characteristics imposed by either the quadratic or von Liebig model are not reasonable for all plant growth situations. Indeed, there is little empirical support for yield decreases due to excessive application of many plant nutrients as implied by the quadratic specification. Further, for some data sets and plant growth situations macronutrient isoquants may not be strictly fixed proportion, contrary to the implication of a von Liebig function. In the case of nitrogen and phosphorus on corn the possibility of $\sigma > 0$ and a growth plateau has considerable intuitive appeal.

A function that allows for convex, but not necessarily right-angle isoquants and that will accommodate plateau growth is the Mitscherlich-Baule:

$$(3)\quad Y_i = \beta_0[1 - \exp(-\beta_1(\beta_2 + N_i))][1 - \exp(-\beta_3(\beta_4 + P_i))].$$

The Mitscherlich-Baule is appealing for a number of reasons. First, the function is flexible regarding the degree of isoquant convexity, accommodating cases of near perfect factor substitution ($\sigma \rightarrow \infty$) to cases of near zero factor substitution ($\sigma \rightarrow 0$).

For the Mitscherlich-Baule, the elasticity of factor substitution at the *i*th data point is

$$(4)\quad \sigma_i = \frac{Y_i[f_N N_i + f_p P_i]}{N_i P_i[2 f_N f_p + \beta_3 Y_i f_N + \beta_1 Y_i f_p]},$$

where $f_N = \beta_0\beta_1[1 - \exp(-\beta_3(\beta_4 + P_i))] \exp(-\beta_1(\beta_2 + N_i))$ and $f_p = \beta_0\beta_3[1 - \exp(-\beta_1(\beta_2 + N_i))] \exp(-\beta_3(\beta_4 + P_i))$ are first derivatives evaluated at N_i and P_i, respectively.[2] As N_i and

[1] Similar analyses have been conducted by Havlicek and Seagraves, Bay and Schoney, and Griffin et al.

[2] For the function given in equation (3), $f_{NN} = -\beta_1 f_N$, $f_{pp} = -\beta_3 f_p$, and $f_{NP} = f_N f_p / Y$. Substitution of these results into the usual formula for σ yields equation (4).

P_i get arbitrarily large, the isoquants approach the limiting case of no factor substitution (right-angle isoquants). As N_i and P_i get small, σ_i increases, suggesting greater factor substitution. Thus, the Mitscherlich-Baule has sufficient flexibility to accommodate limited factor substitution if the data and production process so suggest. Second, the Mitscherlich-Baule, like the von Liebig, imposes plateau growth. For many (although probably not all) plant nutrient response relationships, this feature has considerable appeal. Finally, as mentioned earlier, inclusion of the Mitscherlich-Baule as an option along with the quadratic and von Liebig allows the analyst a broader range of possibilities in terms of isoquant pattern and plateau versus yield decline in model evaluation.

With the addition of an additive random error, $\epsilon_i \sim nid(0, \sigma^2)$, equations (1)–(3) provide a relatively simple framework for evaluating the elasticity of substitution between nitrogen and phosphorus and the existence of a growth plateau for corn. As outlined in APW, a formal test of the implicit hypotheses must be based on nonnested hypothesis testing procedures.[3] However, various asymptotically equivalent nonnested test statistics include the J-test and P-test based on compound regression models (Davidson and MacKinnon), the N-test derived from a likelihood ratio (Cox 1961, 1962; Pesaran 1974; Pesaran and Deaton), and the "adjusted" N- and W-tests which correct for size in small samples (Godfrey and Pesaran). As a practical matter, the choice of which test statistic to use in finite samples depends largely on the nature of the problem.

Most applications of nonnested testing have involved linear models such as equation (1). With the Mitscherlich-Baule function as an alternative the nonnested test statistic must be applicable for nonlinear models. Versions of the J-test, P-test, and N-test (but not the W-test or "adjusted" N-test) have been developed explicitly for nonlinear models. Further, both the J-test and P-test may be used to evaluate more than one (possibly nonlinear) alternative jointly, e.g., the quadratic versus the von Liebig and Mitscherlich-Baule. The latter joint tests are more powerful than pairwise comparisons with more than two competing hypotheses (Davidson and MacKinnon, Wisley and Johnson).

In finite samples inferences based on the J-test, P-test and N-test could conflict because the tests are equivalent only asymptotically. Although not explicitly for nonlinear alternatives, Pesaran found that the N-test performed satisfactorily for samples of 100 observations. The J-test and P-test may still lack power even in such moderately sized samples. However, comparing the results across versions indicates the robustness of the three nonlinear tests. This approach was taken in the following application.

Empirical Results

The estimated models corresponding to equations (1)–(3) are presented in the first three sections of table 1.[4] Parameter estimation was based on data from an agronomic experiment involving the yield response of corn to application of nitrogen and phosphorus (Heady, Pesek, and Brown). The sample data contain 114 observations.

In general, the estimated regression coefficients are statistically significant at the 5% level with few exceptions. The R^2 statistics are relatively high and comparable in magnitude. However, the quadratic does not appear to fit the data as well as the von Liebig or the Mitscherlich-Baule. Further, the signs and relative magnitudes of the estimated coefficients suggest that each curve fulfills the usual regularity conditions.

As noted above, both the von Liebig and Mitscherlich-Baule impose a growth plateau. Moreover, estimated growth plateaus for the Mitscherlich-Baule and the von Liebig exhibit little discrepancy. This plateau is estimated as 127.631 bushels for the Mitscherlich-Baule and 124.610 bushels for the von Liebig. Agreement between the estimated plateaus and the superior fit of the plateau models when compared to the polynomial suggest that, for this data set, corn response to nitrogen and phosphorus displays a growth plateau. However, such an analysis does not give much insight about the degree of factor substitution. Further analysis requires a more formal comparison of the models.

[3] Simply put, nonnested hypotheses result in regression models when no model of interest is more general than all potential alternatives. In the nested case, the restrictions implied by the null hypothesis can be imposed on the more general model and evaluated using the usual Neyman-Pearson approach. When there is no such general model of interest (a nonnested case) the procedure outlined by Cox (1961), where each model is temporarily held as the null and compared to all alternatives is appropriate. Unlike the nested case, such an approach can result in rejection or acceptance of all hypotheses.

[4] Estimation of the parameters for the von Liebig model is outlined in Paris and Knapp. A more theoretical discussion of such segmented regression models is given in Feder.

Table 1. Production Function Estimates and Related Statistics

Quadratic:

$$Y_i = -7.509 + .584N_i + .664P_i - .00158N_i^2 - .00180P_i^2 + .000811N_iP_i$$

(6.637) (.0635) (.0635) (.000177) (.000177) (.000155)

d.f. = 108 $R^2 = 0.832$ SSE = 40728.9

von Liebig:

$$Y_i = \min(124.610);\ 29.041 + .960N_i;\ 20.020 + 1.222P_i)$$

(1.893) (3.308) (.0728) (3.153) (.0779)

d.f. = 109 $R^2 = 0.912$ SSE = 21256.3

Mitscherlich-Baule:

$$Y_i = 127.631[1 - \exp(-.0191(N_i + 13.361))][(1 - \exp(-.0275(P_i + 5.603))]$$

(2.423) (.00220) (2.580) (.00322) (1.436)

d.f. = 109 $R^2 = .924$ SSE = 18551.8

"Translog" approximation:

$$Y_i = .0412(N_i + 24.380)^{2.554}(P_i + 2.0877)^{.304} \exp[.123\log(N_i + 24.380)\log(P_i + 2.0877)$$

(.105) (9.340)(.949) (1.729)(.355) (.0366) (9.340) (1.729)

$$- .292(\log(N_i + 24.380))^2 - .0845(\log(P_i + 2.0877))^2]$$

(.0915) (9.340) (.0356) (1.729)

d.f. = 106 $R^2 = 0.935$ SSE = 15847.3

Note: Statistics in parentheses are standard errors.

The nonnested hypothesis test results are presented in table 2. Because there is no "true" null hypothesis, the tests are performed by temporarily holding each hypothesis as null and testing in a pairwise fashion with each temporary alternative. In some cases, the alternative is comprised of several hypotheses. Such comparison produces a matrix of results (table 2). In this matrix, each group of three rows corresponds to the comparison of the null models against each alternative. The first element in each group is the value of the N-test, the second element is the value of the P-test, and the third element is the value of the J-test. The final group of statistics corresponds to the test against both alternatives jointly. With only one alternative, each test statistic is distributed as a standard normal under the null. In the joint case, the test statistic is distributed under the null as a chi-square random variable with degrees of freedom equal to the number of hypotheses in the alternative.

The results in table 2 illustrate several characteristics of nonnested tests. First, when the temporarily held null hypothesis is linear in all parameters the J-test and P-test are equivalent. Hence, the values in the last two rows of each group are equal when the quadratic is the null (the first column). Second, the relative values of the test statistics support a tendency of the "pairwise" J-test and P-test to overreject the null even with a moderately sized sample. In partic-

Table 2. Nonnested Hypothesis Test Results

Alternative Hypothesis	Null Hypothesis[a]		
	Quadratic	von Liebig	Mitscherlich-Baule
Quadratic		−2.823**	−1.673
		2.565*	1.982*
		3.464**	2.572*
von Liebig	−13.645**		−0.442
	10.403**		1.684
	10.403**		1.807
Mitscherlich-Baule	−18.062**	−4.840**	
	12.254**	4.460**	
	12.254**	2.535*	
Both[b]	96.506**	18.888**	7.441*

[a] The statistics in each group are the respective values of the N-test, P-test and J-test. Under the null, each statistic is distributed as standard normal. A single asterisk indicates statistical significance at the 5% level. Two asterisks correspond to significance at a 1% level.

[b] Comparison of the null hypothesis to both alternatives jointly. Under the null, the statistic is distributed as chi-square with two degrees of freedom.

ular, the temporary null is often rejected so that the restrictions of neither model in a particular comparison are supported. Only in the Mitscherlich-Baule versus the von Liebig comparison is the result conclusive at a 5% significance level. Finally, the implications of the J-test and P-test are seldom transitive, e.g., at a 5% significance level the Mitscherlich-Baule is favored over the von Liebig, but neither the Mitscherlich-Baule nor the von Liebig can be favored over the quadratic.

Because of the shortcomings of the "pairwise" J-test and P-test, inferences from the N-test and "joint" P-test are probably more reliable.[5] The results of these tests suggest that the Mitscherlich-Baule is favored over both the quadratic and the von Liebig. Specifically, N-test values of -18.061 and -1.673 imply that the temporary null of quadratic may be rejected in favor of the Mitscherlich-Baule and that the Mitscherlich-Baule (when null) is not rejected when compared to the quadratic. The Mitscherlich-Baule is also favored when compared to the von Liebig. Finally, when the Mitscherlich-Baule is compared to the quadratic and von Liebig jointly, the null hypothesis cannot be rejected at a 1% significance level.

Thus, these data lend support for the Mitscherlich-Baule, suggesting plateau growth but nonzero elasticity of factor substitution. The isoquant pattern for the estimated Mitscherlich-Baule function is presented in figure 1. While the isoquants have a rectangular-like shape, they do not exhibit fixed proportions. Empirical σ values range from 0.114 at $N = 40$ and $P = 320$ to 0.732 at $N = P = 40$. Of course as either N or P is allowed to get large, σ approaches zero (the flat or vertical portions of the isoquants) implying no factor substitution. This result supports the "law of the minimum" for excessive levels of nutrient when the other is limiting. However, the fact that the isoquants are not everywhere vertical or horizontal suggests some substitution possibilities even if over a narrow range.

Cost of Mispecification

The results of the preceding analysis suggest that, for these data, corn yield displays a nonzero elasticity of substitution and a growth plateau.

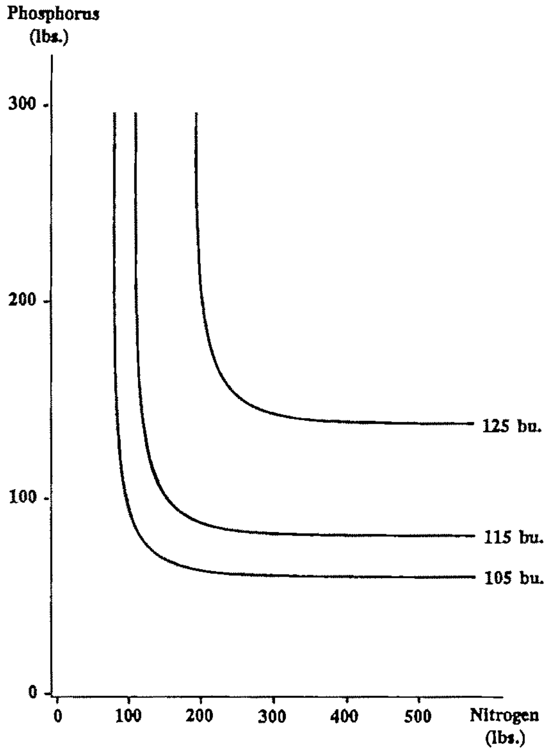

Figure 1. Isoquant pattern for Mitscherlich-Baule

However, as a practical matter, it is important to know the cost of imposing an elasticity of substitution equal to zero or no growth plateau. It is also important to determine the cost of using a model that is parsimonious in parameters but imposes certain technical characteristics a priori on the production process. In either case, this cost is the loss in profits of using the "wrong" production model to derive optimal (profit maximizing) inputs levels.

A demonstration of the relative costs of parsimony or model misspecification is presented in table 3. Using 1988 prices, the implied profit-maximizing levels of nitrogen and phosphorus and corresponding net returns were determined for each function. The optimal values differ considerably among the parsimonious forms. The quadratic implies relatively large input levels when compared to the von Liebig and the Mitscherlich-Baule. However, the difference is much more pronounced between the von Liebig and the quadratic.

The cost of incorrectly specifying one of the parsimonious forms is quantified by comparing net returns given that one of the functions is the true function. For instance, if the true response

[5] Although the J-test may be used for joint comparison, it is difficult to determine when the null is nonlinear. For this reason, it was not calculated.

Table 3. Optimal Values and Relative Cost of Misspecification

"True" Function	Optimal[a] Values	Cost of Applying Optimal Levels Based on[b] Quadratic	von Liebig	Mitscherlich-Baule	"Translog"
		($/ac.)			
Quadratic	209.50 lbs. N 205.02 lbs. P 232.85 net $	0.00	77.39	28.40	23.63
von Liebig	99.54 lbs. N 85.60 lbs. P 244.12 net $	48.26	0.00	20.34	21.96
Mitscherlich-Baule	159.00 lbs. N 124.00 lbs. P 211.96 net $	14.21	15.38	0.00	0.38
"Translog"	155.00 lbs. N 135.00 lbs. P 215.07 net *	9.68	12.65	0.34	0.00

[a] Optimal levels of nitrogen (lbs.), phosphorus (lbs.) and net returns ($) assuming a corn price of $2.27 per bu., a nitrogen price of $0.20 per lb. and phosphorus price of $0.22 per lb.
[b] The decrease in net returns (return over fertilizer costs) by applying the input levels implied by an "incorrect" function. For example, if the "true" function is quadratic net returns from applying 209.50 lbs. N and 205.02 lbs. P is $232.85 per acre. However, if the von Liebig optimal input levels (99.54 lbs. N and 85.90 lbs. P) were applied instead, net returns would be reduced by $77.39 per acre.

was characterized by $\sigma = 0$ and an asymptotic growth plateau, i.e., the von Liebig was "true," using the input levels implied by the quadratic would decrease return over fertilizer costs $48.26 per acre. Further, if the Mitscherlich-Baule was true ($\sigma > 0$ and growth plateau), net returns would be decreased by $14.21 per acre by using the quadratic input levels.

Notice (table 3) that the restriction of a nonzero elasticity of substitution and a growth plateau is the least costly among the parsimonious forms for these data and prices. Specifically, if the Mitscherlich-Baule is specified and the "true" function is the von Liebig or the quadratic, the decrease in net returns is small relative to the other misspecifications.

Optimal levels were also determined using a "translog" approximation which appears to fit the data better than any of the parsimonious forms but at the expense of three additional parameters when compared to the von Liebig and Mitscherlich-Baule and two more when compared to the quadratic.[6] Such additional parameters allow for a more flexible approximation of the response surface; however, because of this flexibility, both a concise interpretation of the parameter values and calculation of optimal input values is difficult. Comparing the cost of using the more parsimonious forms when the "translog" is assumed correct illustrates the impact of using such restrictive forms.

If the "translog" is the appropriate approximation for the underlying response curve, the cost of specifying either a von Liebig or quadratic is substantial (table 3). However, the implicit cost of using the Mitscherlich-Baule is relatively small. Thus, the cost of imposing either zero elasticity of substitution and a growth plateau or nonzero elasticity of substitution and no plateau can be substantial.

Concluding Comments

Both statistical analysis and comparison of the costs of misspecification suggest that for this data set corn response is characterized by a nonzero elasticity of substitution and a growth plateau. This result is relatively robust among the various nonnested test statistics used. It was further shown that the cost (in terms of foregone profit resulting from incorrect optimal input levels) from specifying the response function as either quadratic or von Liebig could be substantial for these data.

In comparison to the findings of Paris and his

[6] Experience with this "translog" function suggests that it may not be a viable approximation for all data configurations. However, because the function was included only for comparison, a search for a more robust approximation was not attempted. Two possible alternatives are the augmented Fourier transformation (Gallant) and cubic splines (Poirier). Each require estimation of a large number of parameters but could be used for comparison as the "translog" approximation was used in this study.

co-workers, our results support the idea of plateau growth; however, the hypothesis of no input substitution over the entire input space was not supported. Indeed there may be agronomic applications (e.g., the application of nitrogen under dryland farming conditions) where the idea of plateau growth also is questionable. There are no doubt many applied situations where the "law of the minimum" is an appropriate specification; but just as a polynomial specification should not be assumed a priori, neither should a von Liebig model.

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Optimal Strategies for Marketing Calves and Yearlings from Rangeland

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Many of the problems encountered in ranching stem from the uncertainty associated with forage availability and the relatively stable forage requirements of the traditional cow-calf operation. This results in underutilization of forage during forage surpluses and costly overutilization during shortages. Smaller cow herds combined with the possibility of carrying calves over to the following spring and/or fall allows forage requirements to be manipulated in response to forage availability. Dynamic programming results suggest that smaller cow-calf-yearling operations have potential to increase expected net returns over a larger cow-calf operation.

Key words: calf and yearling marketing, dynamic programming, forage utilization.

Stochastic weather conditions result in considerable variation in range forage availability. Many of the management decisions made by ranchers are reactions to current range conditions. The most common reaction at the onset of adverse range conditions is supplemental feeding. More dramatic responses, such as reducing herd size, are usually reserved for extended periods of severe forage shortages. On the other hand, when range conditions are good, forage is often underutilized. This inefficient use of the forage resource contributes to the low returns associated with cow-calf operations.

Increased efficiency and reduced risk could possibly be achieved through smaller breeding herds and utilization of flexible marketing strategies. A smaller breeding herd would result in less required feeding during routine forage shortages and lower probability of having to reduce breeding stock numbers during prolonged shortages. The reduced revenue associated with the smaller herd could potentially be offset by retaining weaned calves during periods of excess forage and selling them as yearlings. Excess forage would be converted to weight gain by the calves, leading to a possible increase in revenues. The effect of this type of operation is that livestock forage demands are inexpensively manipulated in response to forage production.

Another advantage of this strategy is that it may be possible to take advantage of seasonal price fluctuations (Faminow and Gum). During the fall, when supply of calves is highest, calf prices are usually at their lowest yearly price. Carrying weaned calves over the winter and spring would permit ranchers to benefit from the seasonally higher spring and summer prices. While prices of heavier calves are traditionally discounted relative to lighter animals, capturing seasonal price fluctuations could potentially offset this loss (Rodriguez and Taylor).

Decision rules for marketing cattle have been determined by comparing expected value of weight gains with expected costs (Bullock and Logan; Fisher; Kennedy; Rodriguez and Taylor; Clark and Kumar; Yager, Greer, and Burt). Strategies developed in these studies utilized deterministic weight gains and stochastic livestock prices in establishing the benefits of retaining livestock. In feedlot situations, costs were considered deterministic because feed requirements can be estimated relatively accurately for any given level of weight gain. In rangeland situations, however, costs were considered stochastic because uncertainty associated with feed purchases is considerably greater. Stochastic livestock prices and range conditions have been considered separately in rangeland models

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(Fisher, Lambert, Rodriguez and Taylor). However, both sources of uncertainty are relevant in determining optimal management strategies.

The objective of this paper is to determine potential economic benefits of smaller cow herds using flexible marketing strategies. To accomplish this objective, a dynamic programming model which includes both stochastic prices and range condition is developed. Conventional cow-calf operation is contrasted to the more flexible cow-calf-yearling marketing strategy.

The Planning Environment

The model is developed for a 3,000-acre pasture at the Texas Experimental Ranch at Throckmorton. The climate is highly variable, with annual rainfall ranging from 18 to 33 inches (VanTassell, Heitschmidt, and Conner). The existing spring calving cow-calf operation is stocked with 325 cows producing an annual average of 260 weaned calves weighing 537 pounds. Current operations are contrasted with a cow-calf-yearling operation based on a light to moderate stocking rate of 275 cows. In comparing the two operations, it is assumed that when forage shortages occur, the rancher provides supplemental feed to maintain desired animal performance. Therefore, weaning percentages and weights are assumed to be the same for the two operations. Further, it is assumed that the quantity of forage demand for each class of cattle is known for each month of the year and that supplemental feed can be directly substituted for forage.

In October, the ranch manager of a cow-calf-yearling operation considers the number of weaned calves to sell or, inversely, the number of calves to retain until spring. The major factors influencing this decision are current forage availability and calf prices. Current forage availability is the primary indicator of the quantity of forage that will be available over the winter; therefore, it is an indicator of the feed costs associated with carrying a given number of cows and yearlings over the winter.

The current price for calves influences the sell decision because price in conjunction with weight determines the current value of each calf. In response to low prices, the manager may carry livestock forward in expectation of higher prices. Alternatively, high prices may induce the sale of livestock in the current period.

The expected returns from retaining livestock and selling them in the future is a function of expected future prices and livestock weight. In this analysis, livestock weights are the average of those expected from retaining equal numbers of steer and heifer calves. That is, the decision on the proportion of steer and heifers to retain is not considered in this analysis.

May is selected as the second decision point during the year. Most forage is produced in the early spring, and by late May a rancher will have a good indication of the amount of forage that will be available for the remainder of the production year. The rancher, in a manner similar to the October decision, determines the number of short yearlings to sell, and the process moves to the October decision point again where all long yearlings (any calves retained from last year's calf crop) are sold. The decision process then begins again with the current year's calf crop. This two-stage decision process is repeated for each year of the planning horizon.

Dynamic Programming Model

Specification of the cow-calf-yearling dynamic programming (DP) model requires one deterministic state variable, inventory of yearlings on hand (I), and two stochastic state variables, amount of forage available [standing crop (SC)] and nominal cattle prices (P). Two decision points or stages within the year are considered, May and October. The inventory state variable represents the number of short yearlings in May and the number of long yearlings in October. Standing crop represents the amount of forage the rancher anticipates being available from the current stage to the next. In October, the price state variable represents calf prices, whereas in May it represents short yearling prices. Control of the system is exerted by selecting the number of calves to sell in October and the number of yearlings to sell in May (D). This decision influences the inventory state variable directly and the standing crop state variable indirectly through forage demand.

Quantification of standing crop and price is achieved by approximating discrete intervals for these continuous variables. Eight equally spaced intervals between 0 and 2,856 pounds per acre are modeled for standing crop. Cattle prices, which range between \$30 per hundredweight and \$85 per hundredweight, are subdivided into eleven intervals of equal width. Both standing crop and price state variable intervals are represented by the interval midpoints. The decision variable and the livestock inventory state vari-

able are represented by eleven values starting at 0 and increasing by increments of 10% of the weaned calf crop.

The assumed objective is to maximize the expected present value of net returns associated with the cow-calf-yearling operation over a ten-year planning horizon. This leads to the general recursive equation:

$$(1) \quad F_n(I, SC, P) = \max_D \{R_n(I, SC, P, D) + \beta_n E_p E_{SC} F_{n-1}(I, SC, P)\},$$

where $F_n(I, P, SC)$ is the expected present value of net returns from following an optimal policy with n stages remaining in the planning horizon given I, P, and SC at stage n; $R_n(I, P, SC, D)$ is the immediate net returns associated with decision D given I, P, and SC at stage n; β_n is the one-period discount factor; E_p and E_{SC} are the expectation operators taken over price and standing crop; max is the maximization operator; and I, P, and SC are as defined earlier. For compactness, subscripts for the current stage are suppressed on the state variables in equation (1). Further, equation (1) follows the convention of numbering stages according to the number of stages remaining in the planning horizon, that is backwards numbering of stages.

Various components make up the immediate net returns function, $R(I, SC, P, D)$. The most obvious component is returns from the sale of calves or yearlings. These returns are calculated as price multiplied by an assumed weight minus an $8.00 per head commission charge. Weaned calves in October are assumed to weigh 5.37 hundredweight, whereas short yearlings in May weigh 7.05 hundredweight. Within the model, any remaining calves from last year's crop (long yearlings) are sold in October. Returns from the sale of long yearlings is calculated in an identical fashion as returns from calves or short yearlings with the following exception. Recall that the price state variable in October is the price of calves. In order to reduce the dimensionality of the model, a relationship between calf prices and long yearling prices is included. By using this relationship, a state variable representing long yearling prices is not necessary. The following relationship was estimated using auction report data (Texas Department of Agriculture) on October calf prices and October prices for livestock weighing the same as the long yearlings for the years 1975–88,

$$(2) \quad \underset{(1.667)}{DIF = -4.2917} + \underset{(.0308)}{.12833P}, \quad \bar{R}^2 = .57,$$

where DIF is the difference between calf and long yearling prices, P is the price of calves, and standard errors are in parentheses. This relation is used to reduce the price received for long yearlings as a function of calf prices. Long yearlings are assumed to weight 7.95 hundredweight.

A second component of $R_n(I, SC, P, D)$ is variable costs associated with the operation. Each October, a variable cost of $114.83 per cow is imposed on the immediate returns function. A per head charge for retaining yearlings of $27.05 is imposed in May and $48.26 in October. For all livestock classes these costs include labor, salt, minerals, veterinary services and medicine, repairs, fuel, machinery, and equipment. These costs and the commission charge were obtained from livestock enterprise budgets developed by the Texas Agricultural Extension Service. An index of production items, interest, taxes, and wage rates for the years 1977–87 showed an average yearly increase of 4.6% (USDA). Variable costs and commissions were inflated at this annual rate.

The final major component in $R_n(I, SC, P, D)$ is supplemental feed costs. When livestock forage demands are greater than available standing crop, the difference is made up by feeding range cubes to maintain desired animal performance. The cost of feeding range cubes is based on the National Research Council guidelines that range cubes are substituted at 44% of the range forage shortage. This cost is calculated as

$$(3) \quad FC_n(SC, I_{n-1}) = .08(.44)\,(TFD_n(I_{n-1}) - TSC_n(SC)),$$

where $TFD_n(I_{n-1})$ is total forage demand of all livestock, $TSC(SC)$ is total standing crop, and .08 represents the cost of range cubes in dollars per pound. Forage demand is based on weighted average requirements of 24.4 pounds per day and 14.0 pounds per day during the October to May grazing period for cows and short yearlings. During the May to October period, forage requirements are 31.1 pounds per day and 24.7 pounds per day for cows and long yearlings (Reichers, Conner, and Heitschmidt). Total standing crop is the product of standing crop yield (lb./ac.), number of acres and utilization rate. Utilization rates of 57% and 33% indicate the weighted average percent of standing crop that may be grazed during the October to May and May to October periods (Reichers, Conner, and Heitschmidt). Feed costs are assumed to remain constant as no price trends were detected in protein supplements.

The discount rate is based on annual nominal inflation rate of 9%, which represents the yield on ten-year government bonds. The terminal value of the process is given by the liquidation of all nonbreeding stock. That is, both the current year's calf crop and all long yearlings are sold, as the terminal stage is assumed to occur in October.

Markovian Relationships

Equation (1) is numerically solved by backward enumeration subject to transition equations for the state variables. The deterministic inventory transition is

$$(4)\qquad I_{n-1} = .8\,(CW) - D \quad \text{if } n-1 \text{ represents May, and} \qquad = I_n - D \quad \text{if } n-1 \text{ represents October,}$$

where CW is the number of brood cows, .8 is the calving rate, and I and D are as defined earlier.

A modified version of a simulation model developed for the Texas Experimental Ranch is the basis for determining the standing crop transition equations (Reichers, Conner, Heitschmidt). Ranch weather data from 1950 through 1985 were used to simulate thirty-six years of standing crop, for October and May, for six levels of brood cows, from 250 to 325 cows by increments of 25 cows, and each of the eleven inventory levels of yearlings associated with a particular herd size. The effect of cows and yearlings on available forage was assumed directly proportional to forage deficits or surpluses in the simulation model (Heitschmidt, Dowhower, and Walker). Standing crop data for October was regressed on May standing crop, the number of breeding cows, and the number of yearlings retained. May standing crop was estimated using October standing crop and livestock numbers. These estimated equation are

$$(5)\qquad SC_{\text{Oct}} = \underset{(56.763)}{1553.7} + \underset{(.01031)}{.28532}SC_{\text{May}} - \underset{(.08418)}{1.1513}LYRLS - \underset{(.15970)}{1.9267}CW + e_1, \qquad \bar{R}^2 = .45 \quad \hat{\sigma} = 349.53, \text{ and}$$

$$(6)\qquad SC_{\text{May}} = \underset{(98.288)}{845.65} + \underset{(.02433)}{.68762}SC_{\text{Oct}} - \underset{(.13261)}{.80138}SYRLS - \underset{(.25132)}{1.3718}CW + e_2 \qquad \bar{R}^2 = .39 \quad \hat{\sigma} = 538.50,$$

where $LYRLS$ is the number of long yearlings, and $SYRLS$ is the number of short yearlings (standard errors in parentheses). Although statistical relationships when using simulated data are meaningless, the two standing crop equations appear to show a strong Markovian relationship.

Recall that the price state variable represents calf prices in October and short yearling prices in May. Therefore, the average monthly price of short yearlings in May was used to predict October calf prices, and average monthly October calf prices were used to predict May short yearling prices. The estimated price equations based on Amarillo auction data for the years 1975–88 are

$$(7)\qquad \ln(P_c) = \underset{(.35697)}{-.67919} + \underset{(.091055)}{1.1753}\ln(P_{sy}) + e_3 \qquad \bar{R}^2 = .93 \quad \hat{\sigma} = .08, \text{ and}$$

$$(8)\qquad \ln(P_{sy}) = \underset{(.48127)}{1.4354} + \underset{(.12244)}{.64735}\ln(P_c) + e_4 \qquad \bar{R}^2 = .70 \quad \hat{\sigma} = .14,$$

where P_c is the price of calves, P_{sy} is the price of short yearlings, and ln is the natural logarithm (standard errors are in parentheses). Equations (7) and (8) indicate the existence of a strong Markovian relationship between the price variables.

Stochastic transitions for prices and standing crop are developed by fitting four different cumulative distribution functions for the error terms associated with equations (5) through (8). The approach, which utilizes a hyperbolic tangent function to estimate the distributions (Taylor 1984), allows conditional probabilities to be generated (Taylor 1986). Maximum likelihood estimates of the cumulative distribution for standardized error terms associated with equations (5) through (8) are as follows:

$$(9)\qquad F(e_1) = .5 + .5\,\text{Tanh}\,(\underset{(.018)}{.040836} + \underset{(.015)}{.801909}\,e_1),$$

$$(10)\qquad F(e_2) = .5 + .5\,\text{Tanh}\,(\underset{(.018)}{.096422} + \underset{(.016)}{.864450}\,e_2),$$

$$(11)\qquad F(e_3) = .5 + .5\,\text{Tanh}\,(\underset{(.227)}{-.0154} + \underset{(.200)}{.9281}\,e_3),$$

$$(12)\qquad F(e_4) = .5 + .5\,\text{Tanh}\,(\underset{(.238)}{-.0209} + \underset{(.195)}{.9003}\,e_4),$$

(standard errors in parenthesis). These four functions represent the stochastic nature within the model. The stochastic transitions are assumed independent of each other.

Results

Several types of results are presented to compare a cow-calf-yearling operation to a cow-calf operation. First, convergent decision rules are presented for the cow-calf-yearling operation with 275 brood cows. Convergent decision rules for this application have the following property: the decision rule in May for year t is the same as the decision rule for May in year $t + 1$, and similarly for the October decision rule. Second, the present values of expected net returns associated with different initial conditions are presented for a ten-year planning horizon. These net returns are then contrasted with those of a cow-calf operation with 325 brood cows by decomposing the difference in expected net returns between the two operations into a herd size and marketing effect.

Convergent Decision Rules

Optimal decisions converged after five years. Convergent decision rules reduce the difficulty of presenting optimal decisions considerably. It is possible to present the October convergent decisions succinctly because the solution is invariant to the inventory state variable. Recall that all long yearlings must be sold; therefore, a state variable representing the number of long yearlings sold in October has no effect on the current decision.

The convergent October decisions (number of calves sold) for a herd size of 275 cows for each range condition and price state are presented in table 1. Standing crop and price effects are evident in the convergent decision rules with standing crop exerting the strongest influence. A threshold standing crop level is apparent between 536 pounds per acre and 893 pounds per acre. This threshold indicates the amount of forage necessary to support the cow herd without supplementation. Below this level all calves are sold. The decision rule illustrates the economic infeasibility of supplementing calves through the October to May grazing season. A second threshold occurs between the 893 pounds per acre and 1,250 pounds per acre levels. This threshold indicates that at the 1,250 pounds per acre level there is enough forage to support the cow herd and all calves. At the 893 pounds per acre level there is enough forage to support only a few calves.

At the 893 pounds per acre level the first price effect occurs. Prices above \$57.50 induce the sale of all calves. At these prices net returns from selling are greater than discounted expected net returns from retaining calves. As standing crop levels increase, price must increase before calves are sold. Good range conditions in this period allow calves to be retained without supplementation. Prices must increase before the returns from selling calves are greater than the expected net returns from selling them as yearlings.

May convergent decisions vary with respect to the inventory state, but because of the consistency of the optimal convergent decisions a complete presentation is possible. Decision rules are to sell all short yearlings when prices are below \$67.50 per hundredweight and above \$72.50 per hundredweight, regardless of the

Table 1. Convergent Decision Rules Indicating the Number of Calves Sold in October for Cow-Calf-Yearling Operation with 275 Cows

Calf Price (\$/cwt)	Standing Crop (lb/ac)							
	179	536	893	1,250	1,607	1,964	2,321	2,678
32.50	220	220	198	0	0	0	0	0
37.50	220	220	198	0	0	0	0	0
42.50	220	220	198	0	0	0	0	0
47.50	220	220	198	0	0	0	0	0
52.50	220	220	198	0	0	0	0	0
57.50	220	220	198	0	0	0	0	0
62.50	220	220	220	110	0	0	0	0
67.50	220	220	220	220	154	0	0	0
72.50	220	220	220	220	220	66	0	0
77.50	220	220	220	220	220	220	220	220
82.50	220	220	220	220	220	220	220	220

standing crop and inventory states. Factors contributing to these sell decisions are low weight gains during the summer and the discount for heavier livestock in October. Examining the price transition probability distributions showed that the expected difference between short yearling prices and long yearling price is smallest when short yearling prices are $67.50 per hundredweight and $72.50 per hundredweight. The expected value of the modest summer weight gains is not enough to compensate for the reduced value of previous weight increases. Further, all short yearlings are sold if standing crop is below 1,607 pounds per acre, regardless of price and inventory states. Short yearlings are retained only within the small remaining state space defined by prices of $67.50 per hundredweight and $72.50 per hundredweight with standing crop levels of 1,607 pounds per acre, 1,964 pounds per acre, 2,321 pounds per acre, and 2,678 pounds per acre.

Following the optimal decision rules given in table 1 for October results in six possible short yearling inventory levels in May. The six inventory levels are 0, 22, 66, 110, 154, and 220, associated with selling 220, 198, 154, 110, 66, or 0 calves. Optimal convergent May decisions for these six inventory levels and the two price levels which result in the retention of short yearlings are given in table 2. Within a given inventory level, the number of livestock sold decreases as the standing crop level or price increases. Inventory permitting, the number of livestock retained tends to a constant number of short yearlings being retained for each standing crop level and price level. Livestock prices of $67.50 and standing crops of 1,607 pounds per acre, 1,964 pounds per acre, 2,321 pounds per acre, and 2,678 pounds per acre result in 0, 44, 88, and 154 short yearlings being retained. Similarly the number of short yearlings retained with a price of $72.50 and standing crop levels of 1,707 pounds per acre, 1,964 pounds per acre, 2,321 pounds per acre, and 2,678 pounds per acre are 44, 88, 154, and 198, respectively.

Table 2. Convergent Decision Rules Indicating the Number of Short Yearlings Sold in May for the State Space Where Yearlings Are Retained

Inventory Short Yearlings	Short Yearling Price ($/cwt)	Standing Crop (lb/ac) 1,607	1,964	2,321	2,678
22	67.50	22	0	0	0
22	72.50	0	0	0	0
66	67.50	66	22	0	0
66	72.50	22	0	0	0
110	67.50	110	66	22	0
110	72.50	66	22	0	0
154	67.50	154	110	66	0
154	72.50	110	66	0	0
220	67.50	220	176	132	66
220	72.50	176	132	66	22

Present Value of Expected Net Returns

Expected present values of net returns generated from following an optimal policy for the ten-year planning horizon given different initial conditions are presented in table 3. These values assume that no yearlings are on hand at the start of the planning horizon. Net returns range from

Table 3. Expected Present Values of Net Returns for a Cow-Calf-Yearling Operation with 275 Cows Following an Optimal Policy over a Ten-Year Planning Horizon Given Different Initial Conditions

Calf Price ($/cwt)	Standing Crop (lb/ac) 179	536	893	1,250	1,607	1,964	2,321	2,678
32.50	68,322.	100,001.	127,677.	138,765.	144,514.	147,994.	150,024.	151,288.
37.50	88,146.	119,784.	147,396.	158,213.	163,932.	167,388.	169,400.	170,650.
42.50	107,670.	139,258.	166,780.	177,167.	182,849.	186,274.	188,263.	189,495.
47.50	126,377.	157,909.	185,314.	195,083.	200,720.	204,109.	206,069.	207,280.
52.50	144,141.	175,614.	202,879.	211,851.	217,439.	220,787.	222,713.	223,898.
57.50	160,931.	192,348.	219,454.	227,457.	232,994.	236,297.	238,187.	239,345.
62.50	176,715.	208,080.	235,081.	241,882.	247,365.	250,624.	252,478.	253,610.
67.50	191,435.	222,758.	249,712.	256,047.	260,491.	263,711.	265,533.	266,640.
72.50	205,026.	236,315.	263,233.	269,530.	273,423.	275,619.	277,264.	278,350.
77.50	217,443.	248,707.	275,598.	281,865.	285,728.	287,874.	289,097.	289,846.
82.50	228,689.	259,935.	286,805.	293,051.	296,893.	299,016.	300,219.	300,951.

$68,322 for the lowest initial price and standing crop to $300,951 under the highest initial price and standing crop states. The largest portion of this range is caused by price differences. Within the lowest standing crop level net returns are expected to increase by $160,367 if the initial price is $82.50 per hundredweight instead of $32.50 per hundredweight. Incremental initial price increases improve net returns between $11,000 to $20,000 within a given initial standing crop level.

The benefit of an initial standing crop level of 2,678 pounds per acre instead of 179 pounds per acre is $72,262 within the $82.50 price state. The largest share of this improvement occurs between the two poorest standing crop levels. Incremental increases between 179 and 536 pounds per acre result in an increase of $31,246, whereas an initial standing crop of 893 pounds per acre instead of 536 pounds per acre results in an increased net return of $26,870. These improvements illustrate the cost of feeding livestock during initial periods of insufficient forage. Another critical forage level is between 893 pounds per acre and 1,250 pounds per acre, where net returns increase $6,246. At the 1,250 pounds per acre level, there is enough forage to initially carry calves through the October to May grazing season. Further increases in net returns resulting from improved standing crop levels are attributed to the lower probability of transition to poor range condition associated with the better initial range conditions.

Herd and Marketing Effects

The expected net returns from the cow-calf-yearling operation are contrasted with those of a conventional cow-calf operation. The cow-calf operation is modeled by constraining the dynamic programming model to sell all calves in October. As noted earlier, the cow-calf operation is based on the current stocking rate of 325 cows. Table 4 presents the differences in expected present values between the two livestock operations. Adoption of the smaller cow-calf-yearling operation produces substantial benefits given poor initial standing crop and low initial prices. Benefits decline as initial price and range conditions improve, culminating in negative benefits with initially high prices and standing crops. Negative values reflect the better performance of the cow-calf operation given these initial states.

Increased insight concerning the cause of these benefits is achieved by decomposing the values in table 4 into a herd and flexible marketing effect. The herd effect is obtained by calculating the differences in expected present value of net returns between conventional cow-calf operations with 325 cows and 275 cows. Expected gains from operating a smaller herd given different initial conditions are shown in table 5. A disadvantage of the larger herd is the increased probability of having to feed. At initial low prices and poor standing crop levels, the cost of feeding the larger herd completely overshadows the revenues from increased calf sales. With initial poor range conditions and high prices the differences are still large, but higher prices partially compensate for large feeding costs. Even with good initial standing crop, the smaller herd performs better under low prices. Only at initially high prices and good range conditions do the net returns from the larger herd exceed those of the smaller herd. Although these results are

Table 4. Expected Gain in Present Value of Net Returns for A Cow-Calf-Yearling Operation with 275 Cows Following an Optimal Policy over a Conventional Cow-Calf Operation with 325 Cows over a Ten-Year Planning Horizon Given Different Initial Conditions

Calf Price ($/cwt)	Standing Crop (lb/ac)							
	179	536	893	1,250	1,607	1,964	2,321	2,678
32.50	54,973.	53,520.	47,729.	42,969.	40,770.	38,997.	37,864.	37,177.
37.50	50,046.	48,552.	42,697.	37,666.	35,437.	33,640.	32,489.	31,788.
42.50	45,140.	43,596.	37,651.	32,190.	29,924.	28,096.	26,922.	26,203.
47.50	40,440.	38,840.	32,778.	26,699.	24,388.	22,524.	21,321.	20,581.
52.50	36,027.	34,369.	28,167.	21,290.	18,931.	17,025.	15,789.	15,023.
57.50	31,947.	30,233.	23,872.	16,027.	13,616.	11,665.	10,393.	9,600.
62.50	28,225.	26,459.	19,993.	10,946.	8,481.	6,486.	5,178.	4,359.
67.50	24,867.	23,058.	16,545.	7,032.	3,528.	1,495.	154.	−690.
72.50	21,867.	20,024.	13,475.	3,924.	−131.	−3,188.	−4,706.	−5,571.
77.50	19,210.	17,342.	10,766.	1,185.	−2,900.	−6,007.	−7,947.	−9,149.
82.50	16,870.	14,985.	8,388.	−1,215.	−5,321.	−8,451.	−10,410.	−11,629.

Table 5. Expected Gain in Present Value of Net Returns from Conventional Cow-Calf Operation with 275 Cows Instead of 325 Cows over A Ten-Year Planning Horizon Given Different Initial Conditions

Calf Price ($/cwt)	Standing Crop (lb/ac) 179	536	893	1,250	1,607	1,964	2,321	2,678
32.50	45,320.	43,385.	36,733.	27,071.	22,902.	19,711.	17,690.	16,419.
37.50	41,512.	39,578.	32,925.	23,264.	19,095.	15,903.	13,882.	12,611.
42.50	37,754.	35,819.	29,167.	19,505.	15,336.	12,144.	10,123.	8,852.
47.50	34,153.	32,218.	25,565.	15,904.	11,735.	8,543.	6,522.	5,251.
52.50	30,741.	28,807.	22,154.	12,492.	8,324.	5,131.	3,111.	1,840.
57.50	27,530.	25,596.	18,943.	9,282.	5,113.	1,920.	−100.	−1,371.
62.50	24,529.	22,595.	15,942.	6,281.	2,112.	−1,081.	−3,101.	−4,372.
67.50	21,748.	19,813.	13,161.	3,499.	−1,670.	−3,862.	−5,883.	−7,153.
72.50	19,196.	17,261.	10,608.	947.	−3,222.	−6,414.	−8,435.	−9,706.
77.50	16,877.	14,942.	8,289.	−1,372.	−5,541.	−8,733.	−10,754.	−12,025.
82.50	14,786.	12,852.	6,200.	−3,463.	−7,632.	−10,824.	−12,844.	−14,114.

measured in terms of returns net of specified variable cost, the smaller herd would also result in lower annual capital costs due to the smaller investment in the cow herd.

Marketing effects are determined by comparing a 275-head cow-calf-yearling operation to a 275-head cow-calf operation. The expected gains in the net present values from adoption of the flexible marketing strategies given different initial conditions are shown in table 6. These gains result from more efficient utilization of forage and capturing seasonal price differences. Flexible marketing benefits are greatest when initial forage is abundant and price is low. Under high initial prices, differences are relatively low because all or most of the calves are sold in October under both systems. It is somewhat surprising that the benefits are so large under poor standing crop conditions and low prices because both operations initially sell all calves. Over time, as standing crop improves, the flexible marketing approach benefits from excess forage and seasonally high prices. The only benefit of increased standing crop production for the conventional operation is reduced feed costs.

Alternative Stocking Rates

Benefits from adoption of a cow-calf-yearling operation consist of a marketing and a herd effect. The herd effect represents the change in expected present value of net returns from operating with a smaller breeding herd. The herd effect is negative only when initial standing crop levels are good to high and initial prices are high. This suggests that ranchers could gain from smaller herds under conditions of either initial low prices or low standing crop levels.

Determination of the optimal herd size re-

Table 6. Expected Gain in Present Value of Net Returns for a Cow-Calf-Yearling Operation with 275 Cows Following Optimal Policy over a Conventional Cow-Calf Operation with 275 Cows over a Ten-Year Planning Horizon Given Different Initial Conditions

Calf Price ($/cwt)	Standing Crop (lb/ac) 179	536	893	1,250	1,607	1,964	2,321	2,678
32.50	9,653.	10,135.	10,996.	15,898.	17,868.	19,286.	20,174.	20,758.
37.50	8,534.	8,974.	9,772.	14,402.	16,342.	17,737.	18,607.	19,177.
42.50	7,836.	7,777.	8,484.	12,685.	14,588.	15,952.	16,799.	17,351.
47.50	6,287.	6,622.	7,213.	10,795.	12,653.	13,981.	14,799.	15,330.
52.50	5,286.	5,562.	6,013.	8,798.	10,607.	11,894.	12,678.	13,183.
57.50	4,417.	4,637.	4,929.	6,745.	8,503.	9,745.	10,493.	10,971.
62.50	3,696.	3,864.	4,051.	4,665.	6,369.	7,567.	8,279.	8,731.
67.50	3,119.	3,245.	3,384.	3,533.	4,198.	5,357.	6,037.	6,463.
72.50	2,671.	2,763.	2,867.	2,977.	3,091.	3,226.	3,729.	4,135.
77.50	2,333.	2,400.	2,477.	2,557.	2,641.	2,726.	2,807.	2,876.
82.50	2,084.	2,133.	2,188.	2,248.	2,311.	2,373.	2,434.	2,485.

quires calculating the expected value of the convergent stage returns. However, the difficulty of manipulating two different matrixes of dimension 968 by 968 (11 inventory states × 11 price states × 8 standing crop states) and four vectors of dimension 1 by 968 makes determination of optimal herd sizes impractical.

The marketing effect represents increased returns resulting from selling heavier livestock at higher prices during the summer. As expected, the marketing effect is positive for all initial combinations of state variable levels. This suggests that adoption of a flexible marketing strategy regardless of the herd size chosen will provide increased net returns.

Convergent optimal decision rules are obtained from the DP model for six herd sizes ranging in size from 250 to 375 brood cows. Generally, the convergent decisions are robust with respect to the number of brood cows. The optimal October decision is to sell all calves when standing crop levels are insufficient to support the brood cows. Disregarding price effects, the October decision rule is to keep all calves that the October standing crop levels will support. This rule is modified as higher prices increase the net returns from immediate sale above the expected net returns from retaining livestock. As herd size increases, calves are sold at progressively lower price levels. Larger herds result in lower expected standing crop levels and higher feeding costs in subsequent periods. The expected cost of feeding retained livestock dominates the expected value of weight gain as herd size increases. This influence is evident in the convergent May decisions, where livestock are retained only under very limited conditions and small herd sizes. Larger herds reduce the probability of being able to carry yearlings through the May to October grazing period without supplemental feeding.

Concluding Comments

Results suggest that using smaller cow herds and retaining calves in the fall to sell as short or long yearlings can increase net returns over larger conventional cow-calf operations. The benefits of adopting a flexible marketing plan and decreasing herd sizes can be decomposed into a marketing effect and a herd effect. For a given herd size, the marketing effect is always positive. This is expected because the flexible marketing strategy is a more general strategy that encompasses a conventional marketing plan. The benefits of flexible marketing plans are more efficient use of the forage resource and the potential ability to capture seasonal price fluctuations. For conventional marketing of calves the herd size effect may be positive or negative depending on initial conditions.

Although the specific results reported herein apply only to the Texas Experimental Ranch, they provide guidelines for other areas and operations. Because the largest benefits of cow-calf-yearling operations occur under lower initial standing crop levels, ranchers in more arid and/or more variable rainfall regions would be expected to benefit relatively more from the alternative marketing practices. However, because livestock weight gains, costs, and seasonal forage production would vary between regions and to some extent between ranches within regions, optimal decision rules for other specific ranch situations must be obtained by parameterizing the model for each specific operation.

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The Impact of Information on Environmental Commodity Valuation Decisions

John C. Bergstrom, John R. Stoll, and Alan Randall

A conceptual model is developed which provides insight into how information affects willingness to pay for environmental commodities. A refutable hypothesis of the effects of a specific information type on the magnitude of willingness to pay for an environmental commodity is developed. This hypothesis is tested using a contingent valuation method experiment. Results indicate that information affects willingness to pay in a theoretically plausible manner. The results support the contention that information is important for accurate environmental commodity consumer valuations.

Key words: consumer valuation, contingent valuation, environmental commodities, information effects, welfare measures.

Much progress has been made in the past two decades in the development of techniques for measuring the economic value of environmental commodities (Freeman; Mendelsohn and Brown; Randall, Hoehn, and Brookshire; Ward and Loomis). However, fundamental questions remain concerning the process by which consumers formulate environmental commodity valuations. An especially challenging question is: "What impact does information have on the value consumers place upon environmental commodities?"

A number of previous empirical studies have detected statistically significant changes in environmental commodity valuations induced by changes in the information presented to consumers. Such effects are usually labeled "information biases" (Cummings, Brookshire, and Schulze). Most previous studies, however, do not provide a conceptual model of information effects. Hence, it is difficult to judge whether or not observed information effects induce undesirable biases.

In the next section of this paper, a theoretical model of the effects of a specific type of information on willingness to pay for a change in a rationed environmental commodity is developed. The model focuses upon the effects of information on the marginal utility of an environmental commodity, the perceived utility levels with and without the environmental commodity, and consumer expenditures. An empirical test of a specific information effect hypothesis which arises from the model is then discussed. The results suggest that information influences willingness to pay. The paper ends with a brief summary and conclusions.

Information and Willingness to Pay

This paper focuses upon the impact of "service information" on willingness to pay (*WTP*) for a change in a rationed environmental commodity. Service information (*SI*) describes the possible uses of a commodity. Possible uses can be subjective in nature (e.g., aesthetic enjoyment). *WTP* for increments or decrements in a rational environmental commodity are measured by Hicksian welfare measures (Brookshire, Randall, and Stoll; Randall and Stoll). *WTP* can be derived

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by first specifying an income compensation function.

$$(1) \qquad h[P, Q, V(P, Q, M|SI)],$$

where P is a nonrationed commodity price vector, Q is a rationed environmental commodity, $V(.)$ is an indirect utility function, and M is money income.

The indirect utility function in (1) indicates that utility derived from P, Q, and M is dependent upon available service information denoted by SI. Given (1), WTP is defined by

$$\begin{aligned}(2) \quad WTP &= h[P, Q^c, V(P, Q^c, M^o|SI)] \\ &\quad -h[P, Q^c, V,(P, Q^r, M^o|SI)] \\ &= h[P, Q^c, V^c]-h[P, Q^c, V^r] \\ &= M^o - M^1,\end{aligned}$$

where Q^c is the post-payment quantity of a rationed environmental commodity, Q^r is a reference quantity of a rationed environmental commodity, M^o is the initial income level, M^1 is the post-payment or subsequent income level; V^c is an indirect utility level given Q^c, P, and M^o (post-payment utility level); and V^r is an indirect utility level given Q^r, P, and M^o (reference utility level).

Assume $Q^c - Q^r$ represents an increment in a rationed environmental commodity from an initial quantity, Q^o, to a subsequent quantity, Q^1. In this case $Q^c = Q^1$ and $Q^r = Q^o$, and (2) measures a Hicksian compensating welfare measure associated with the increment. Next, assume $Q^c - Q^r$ represents a decrement in a rationed environmental commodity from an intitial quantity, Q^o, to a subsequent quantity, Q^1. In this case $Q^c = Q^o$ and $Q^r = Q^1$, and (2) measures a Hicksian equivalent welfare measure associated with the decrement.

The impact of information on WTP for an increment or decrement in a rationed environmental commodity is calculated by the partial derivative,

$$\begin{aligned}(3) \qquad \frac{\partial WTP}{\partial SI} &= \frac{\partial h}{\partial V^c}\frac{\partial V^c}{\partial SI} - \frac{\partial h}{\partial V^r}\frac{\partial V^r}{\partial SI} \\ &= g^c\frac{\partial V^c}{\partial SI} - g^r\frac{\partial V^r}{\partial SI},\end{aligned}$$

where g^c is the marginal cost of utility given Q^c and g^r is the marginal cost of utility given Q^r. The terms g^c and g^r are essentially inverses of the marginal utility of money. Equation (3), which assumes SI is variable, indicates that the impact of a change in SI on WTP depends on the differential effect of information on the reference and post-payment utility levels. Assessment of this differential effect is facilitated by expressing WTP as

$$\begin{aligned}(4) \quad WTP &= \int_{Q^o}^{Q^1} - \left[\frac{dh}{dQ}\right] dQ \\ &= \int_{Q^o}^{Q^1} - \left[\frac{\partial h}{\partial Q} + \frac{\partial h}{\partial V}\frac{\partial V}{\partial Q}\right] dQ \\ &= -\int_{Q^o}^{Q^1} [h_Q + g(SI)V_Q(SI)]dQ,\end{aligned}$$

where $g(SI)$ is the marginal cost of utility given SI and $V_Q(SI)$ is the marginal utility of the rationed environmental commodity given SI.

The impact of a change in SI on WTP is then determined by the partial derivative:

$$(5) \quad \frac{\partial WTP}{\partial SI} = -\int_{Q^o}^{Q^1}\left[\frac{\partial g(SI)}{\partial SI}V_Q(SI) + g(SI)\frac{\partial V_Q(SI)}{\partial SI}\right]dQ,$$

where $\partial h_Q/\partial SI$ is assumed to equal zero because SI affects perceptions of only the possible uses of Q, not the actual, objective level of Q. The first term in (5) accounts for the impact of SI on the marginal cost of utility. The second term in (5) accounts for the impact of SI on the marginal utility of the rationed environmental commodity. Hence, the differential effect of a change in SI on the initial and subsequent utility levels is caused by changes in $g(SI)$ and $V_Q(SI)$ which are caused by changes in service information. Because different service information may have different effects on $g(SI)$ and $V_Q(SI)$, predicting the final impact of a change in SI on WTP for a change in a rationed environmental commodity is problematic and must generally proceed on a case by case basis.

A Case Study

A study was conducted to test for the impact of service information on WTP for wetlands protection. The particular wetland area considered is a large section of Louisiana's coastal wetlands. Louisiana contains over 40% of the nation's wetlands resources. The wetlands area considered in this study encompasses approximately 3.2 million acres and represents an important national resource.

Louisiana coastal wetlands are used for recreational activities, such as waterfowl hunting,

saltwater fishing, freshwater fishing, recreational shrimping, and recreational crabbing. These activities are "produced" by individuals or households by combining nonrationed, market commodities (e.g., bait, tackle, boats) and rationed, environmental commodities (e.g., wetlands) (Bockstael and McConnell).

Because of a combination of factors, wetlands in the study area are decreasing at a rapid annual rate. There is much concern over the loss of these national resources among public officials and private recreationists. The welfare impact on recreators of wetlands loss can be measured by their *WTP* to prevent the loss. This *WTP*, which represents a Hicksian equivalent welfare measure, is calculated by (2) where $Q^c = Q^o$ = initial (pre-loss) quantity of wetlands $Q^r = Q^1$ = subsequent (post-loss) quantity of wetlands. In the study, *WTP* for wetlands protection was elicited directly from recreationists using the contingent valuation method (CVM).

Information Effect Hypothesis

A recent survey indicates that consumption services or attributes supported by wetlands in the study area which are most highly valued by recreationists include hunting or fishing success, wildlife encounters or sightings, natural scenery, and remoteness or isolation (U.S. Army Corps of Engineers). In a CVM exercise, recreationists may fail to consider all of these services or attributes when formulating and stating *WTP* to prevent a decrement in wetlands from Q^o to Q^1. This incomplete information processing is supported by Hoehn and Randall's model of valuation decisions in contingent markets. Consideration of these services or attributes may be enhanced by providing CVM participants with service information (*SI*). In the present case study, *SI* represents information which describes consumption services or attributes associated with recreational trips to the wetlands study area.

By helping consumers to recognize or recall desirable consumption services or attributes, it is conjectured that *SI* affects the perceived marginal utility of a given rationed quantity of wetlands. *SI*, it is assumed, does not change perceptions of objective characteristics of the wetlands commodity itself (e.g., total acres). Thus, with or without additional *SI*, CVM participants always valued the same environmental commodity, denoted by Q in (1)–(5). *SI*, however, was assumed to affect perceived consumption services or attributes supported by Q.[1]

If CVM participants do not consider all beneficial consumption services or attributes supported by wetlands, they may underestimate the marginal utility of protected wetlands. That is, they may underestimate the change in total utility or satisfaction that would result from a change in wetlands if they fail to consider all types of benefits. Under these conditions, it is conjectured that additional *SI* that points out the beneficial consumption services or attributes may induce an upward revision in the marginal utility of protected wetlands. In this case, $\partial V_Q(SI)/\partial SI$ in (5) will have a positive sign. Hence, the second term in (5) will be positive since $g(SI)$ is assumed to be positive.

Thus, one hypothesized impact of additional *SI* is to increase *WTP* for wetlands protection by increasing the marginal utility of Q, or $V_Q(SI)$. This increase in *WTP* results from an upward revision in the post-payment utility level relative to the revision in the reference utility level. That is, with additional *SI* a CVM participant perceives himself or herself as gaining more utility from paying to increase wetlands from Q^1 to Q^o. By (3), a relative increase in the post-payment utility level increases *WTP*.

Additional *SI* may also impact the first term in (5). With additional *SI* about generally desirable consumption services or attributes, recreationists may perceive that more utility can be derived from current expenditures. Thus, $g(SI)$ would decrease since an additional unit of utility could be gained with less expenditures. This decrease in $g(SI)$ implies that $\partial g(SI)/\partial SI$ in (5) is negative. The first term in (5) would therefore be negative since $V_Q(SI)$ is assumed to be positive. A negative first term in (5) indicates that additional *SI* will also have the impact of reducing *WTP* for wetlands protection. Such a reduction in *WTP* would result from an upward revision in the reference utility level relative to the post-payment utility level which must occur

[1] Following Lancaster, environmental commodity characteristics are elements of the commodity which "make up" the commodity and are objectively measurable and observable (e.g., size, location). Following household production theory, consumers combine environmental commodity characteristics with other nonrationed market commodities to "produce" consumption activities (e.g., recreational trips). Services or attributes associated with these activities generate utility (Becker, Stigler and Becker, Michael and Becker, Stoll). Unlike commodity characteristics, consumption services or attributes can be subjective and difficult to measure and observe (e.g., aesthetic enjoyment).

so that the reference income level (M^o) remains exhausted. By (3), if the reference utility levels increase, *WTP* decreases.

Hence, the direction of the final expected impact of *SI* on *WTP* for wetlands protection depends on the strength of the differential effect on the reference and post-payment utility levels. That is, the final impact of *SI* on *WTP* depends on how additional *SI* affects recreationists' valuation of the rationed commodity interval given by $Q^o - Q^1$. The experimental hypothesis is therefore a two-tailed test and is stated in alternative form as

$$H^0: WTP(SI^1) = WTP(SI^2)$$
$$H^1: WTP(SI^1) \neq WTP(SI^2),$$

where $SI^1 > SI^2$. H^1 assumed that Grether and Wilde's notion of strong information overload is not a problem. Strong information overload is defined as the emergence of confused or dysfunctional consumer behavior caused by increased information.

Hypothesis Test Methodology

A CVM field survey experiment was conducted to test H^1. The experiment involved bid elicitation using mail questionnaires with different levels of *SI*, bid function estimation, and statistical hypothesis testing.

Survey design and procedures. In the survey questionnaire, a participant was asked to state a maximum acceptable income reduction each year to protect wetlands in the study area. Each participant submitted three bids for wetlands protection. The three bids corresponded to the following three scenarios—*WTP* for wetlands protection assuming: (*a*) current bag and catch levels could be maintained, (*b*) bag and catch levels could be maintained at 50% of current levels, and (*c*) bag and catch levels could be maintained at 25% of current levels.

Two different versions of the contingent market were employed (see appendix). Each version elicited bids under the three-bag scenarios. In each contingent market, the quantity of all types of information except for *SI* were held constant. The *SI* presented in version A did not explicitly remind recreationists of the beneficial consumption services or attributes supported by wetlands. Version B explicitly reminded recreationists of four beneficial consumption services or attributes supported by wetlands; daily bag or catch, wildlife encounters, natural scenery, and isolation or remoteness. Thus, Version B contained a greater level of *SI* than Version A.

Both versions of the questionnaire presented identical characteristic information (CI) which described wetlands in the study area (e.g., location, size, vegetation, water salinity). This information helped ensure that participants receiving both questionnaires perceived and valued the same environmental commodity, *Q*. A cross check, however, was not conducted to ensure that perceptions of the wetland area were uniform across participants because participants were randomly selected and were highly familiar with the wetlands study area. Most respondents indicated that they had been participating in outdoor recreation in the study area for over ten years. Thus, even without the CI provided in the questionnaire, perceptions of the wetlands study area and its characteristics were expected to be highly uniform across CVM participants.

In sum, the different information presented across Versions A and B is assumed not to have changed characteristics of the actual environmental commodity recreationists valued; namely, wetlands in the study area. The different information presented across Versions A and B was intended only to change perceptions of consumption services or attributes associated with wetlands-based recreational trips. The higher level of *SI* presented in Version B suggested that its valuations would be different from valuations elicited by Version A. This expectation was reinforced by the conjecture that as catch and bag were reduced, other consumption services or attributes such as wildlife encounters would become relatively more important.

The two questionnaire versions were randomly assigned across a sample of recreationists. The sample was drawn from a list of recreational users of the study area compiled by the Waterways Experiment Station, U.S. Army Corps of Engineers. The questionnaires were mailed to sample individuals in the summer of 1986. The initial mailing packet included a questionnaire, cover letter, and postage-paid return envelope. One week after mailing the initial mailing packet, a postcard reminder was sent to all sample individuals. Questionnaires were mailed to a total of 230 recreationists. Six of these questionnaires were returned because of insufficient or improper addresses. Thus, the effective sample size was reduced to 224. Of these

224 questionnaires, 139 were returned for a response rate of 62%.

Bid function specification. Economic theory suggests that *WTP* and changes in recreation quantity and quality variables are related in a nonlinear manner. Preference indicator variables such as income and other socioeconomic variables may also be related to *WTP* in a nonlinear manner (Brookshire, Randall, and Stoll; Crocker; Hammack and Brown; Weber). Previous studies also suggest that information may be related to preferences in a nonlinear manner. Grether and Wilde, for example, argue that the effects of information on preferences diminish at successively higher information levels, a phenomenon called weak information overload. A bid function with these properties is specified in general form as

$$(6) \quad WTP = \exp(a_o + a_1{*}k_1 + \ldots + a_N{*}k_N) \cdot \sum_{i=1}^{I} R_i^{bi} = z{*} \sum_{i=1}^{I} R_i^{bi}$$

where a_n is the nth preference indicator or information variable, $n = 1, \ldots, N$; R_i is the change in the ith recreation quantity or quality variable, $i = 1, \ldots, I$; z is a composite constant term; and $a_o, a_1, \ldots, a_N$; $b_i, \ldots, b_I$ are parameters to be estimated. An additional feature of (6) is that the effects of preference indicator and information variables can be collapsed into one constant term, denoted by z. This feature allows dichotomous preference indicator and information variables to contribute to a nonlinear effect on *WTP*.

In order to test H^1, a linear transformation of (6) was specified as

$$(7) \quad LWTP = a_o + a_1{*}INCOME + a_2{*}RECDAY + a_3{*}YEARS + a_4{*}CAMP + a_5{*}SUB + a_6{*}INFORM + b_1{*}LTWFBAG + b_2{*}LTFFCAT + b_3{*}LTSFCAT + b_4{*}LENCOUNT + b_5{*}LBOAT + b_6{*}LPOLL,$$

where *LWTP* is natural log of *WTP* to protect wetlands. The preference indicator variables are as follows: *INCOME* is individual income reported in the survey (continuous group estimates); *RECDAY* is days of all types of outdoor recreation per month; *YEARS* is average years of participation in waterfowl hunting, freshwater fishing, and saltwater fishing; *CAMP* is an indicator variable for hunting or fishing camp ownership (1 = yes, 0 = no). The recreation quantity and quality variables are as follows: *LTWFBAG* is the natural log of annual waterfowl bag (annual waterfowl hunting days × average daily bag); *LTFFCAT* is the natural log of annual freshwater fish catch (annual freshwater fishing days × average daily catch); *LTSFCAT* is the natural log of annual saltwater fish catch (annual saltwater fishing days × average daily catch); *LENCOUNT* is the natural log of daily wildlife encounters (e.g., sightings); *LBOAT* is the natural log of daily nonrecreational boat sightings; and *LPOLL* is the natural log of daily environmental pollution (e.g., litter). Finally, the information variable is *INFORM*, which is an indicator variable for the level of service information (1 = high level; 0 = low level).

Estimation and hypothesis test results. Equation (7) was estimated by pooling bids for the three-bag/catch scenarios and employing regression analysis. The specification of the *INFORM* variable (7) allowed for a test of the hypothesis, H^1. Equation (7) was first estimated by ordinary least squares (OLS). The condition number for this model was twenty-five, which suggests that multicollinearity is not a major concern (Belsey, Kuh, and Welsh; Judge et al., pp. 620–24).

Homoskedasticity tests suggested by Glesjer, however, indicated the presence of heteroskedasticity with respect to two of the bag/catch variables (*LTWFBAG*, *LTSFCAT*). Each of these variables was negatively related to the error variance. These negative relationships are conceptually plausible because as annual bag/catch increases (which accounts for both the quantity and quality of recreation), the effects of extraneous factors on recreation valuation behavior may diminish.

In (6), heteroskedasticity between *WTP* and the bag/catch and recreation day variables was assumed to be reinforcing and of the general multiplicative form; $\sigma_i^2 = \sigma^2{*}TWFBAG^{c1}{*}TSFCAT^{c2}$. This equation was estimated by the transformation, $\ln(e_i^2) = c_o + c_1{*}LTWFBAG + c_2{*}LTSFCAT$. The predicted values of this equation were then used to weight (7) to correct for heteroskedasticity caused by multiple variables as suggested by Kmenta (pp. 285–87). Further homoskedasticity testing failed to reject the hypothesis that the error variance was constant with

respect to *LTWFBAG* or *LTSFCAT* at the .01 level.[2]

The weighted least squares (WLS) estimates for (7) are presented in table 1. Out of the preference indicator variables, *INCOME*, *RECDAY*, *SUB*, and *YEARS* have positive signs. *INCOME* and *YEARS*, however, are not statistically significant (statistical significance levels are indicated in table 1). *CAMP* is statistically significant with a negative sign. *LTWFBAG*, *LTSFCAT*, and *LENCOUNT* have positive signs. Each of these variables was also statistically significant, which suggest they are important determinants of *WTP* for wetlands protection. *LTFFCAT* was statistically significant with a negative sign. *LPOLL* has a positive sign but is not statistically significant. *LBOAT* is statistically significant with a positive sign.

The specification of the *INFORM* variable tests the hypothesis (H^1) of no statistically significant effect of increased *SI* on the magnitude of *WTP*. As indicated in table 1, however, the *INFORM* variable was statistically significant at the .01 level of significance. Thus, the hypothesis of no statistically significant effect is rejected. Moreover, the sign of the regression coefficient is positive. This positive sign suggests that additional *SI* increased *WTP*.

SI Test Implications

The results of the CVM field survey experiment indicate that additional service information (*SI*) induces recreationists to increase *WTP* for wetlands protection. The additional *SI* apparently had a stronger positive impact on the post-payment utility level which, by (3), increases *WTP*. Is this effect of *SI* desirable? This question is difficult to answer. First, if additional *SI* is false

Table 1. WLS Estimates for Wetlands Protection Bid Function

Parameter Estimates (Standard Error)

Intercept	*INCOME*	*RECDAY*	*YEARS*	*CAMP*	*SUB*	*INFORM*	*LTWFBAG*	*LTFFCAT*	*LTSFCAT*	*LENCOUNT*	*LBOAT*	*LPOLL*	$\bar{R}^2$	*F*	*N*
−8.547**	.0000039	1.377**	.010	−1.591*	2.622**	2.392**	.198**	−.206**	.280**	4.666**	.697*	1.058			
(1.76)	(.00001)	(.41)	(.03)	(.68)	(.66)	(.53)	(.07)	(.06)	(.06)	(.96)	(.27)	(.76)	.44	12.628	177

Note: Single asterisk indicates significant at the .05 level; double asterisk indicates significant at the .01 level; $\bar{R}^2$ is adjusted R^2.

[2] It is possible that information also may impact the variance of *WTP*. For example, increased *SI* may increase the uniformity of service or attribute perceptions across respondents and therefore decrease the variance of *WTP*. On the other hand, because respondents' preferences for the additional services or attributes described by *SI* may vary considerably, increased *SI* may increase the variance of *WTP*. The specification of (6) imposes the restriction that if *SI* increases (decreases) *WTP*, it must also increase (decrease) the variance of *WTP*. Hence, the hypotheses about the effect of *SI* on the variance of *WTP* cannot be tested. The homoskedasticity tests on (7) indicated a negative relationship between *SI* and the variance of *LWTP*. This negative relationship disappeared when (7) was estimated by weighted least squares.

It was thought that the nonlinear specification of (6) would provide a stronger test of the effect of information on the magnitude of *WTP*, which was the focus of this study. Further research designed specifically to test for the effects of information and other variables on the variance of *WTP* using less structured bid functions is encouraged.

or misleading, changes in valuations induced by that information are not desirable. For example, if additional *SI* describes nonexistent beneficial consumption services or attributes supported by wetlands, or distorts existing beneficial consumption services or attributes in a positive direction, recreationists may be induced to overstate *WTP* for wetlands protection. Such overvaluation may lead to excess wetlands protection from a benefit-cost or potential Pareto-efficiency standpoint.

Another issue relates to the completeness of information and the certainty of consumer valuation processes. When consumers value a change in a commodity with a positive marginal utility, Hoehn and Randall argue that uncertain valuation processes result in undervaluation of the change. One cause of uncertain consumer valuation processes may be incomplete information.

For example, in the present study it was conjectured that recreationists may not automatically consider all of the beneficial consumption services or attributes supported by wetlands when valuing wetlands protection. Thus, as Hoehn and Randall suggest, CVM participants not given additional *SI* may have undervalued wetlands protection. Such undervaluation may result in underprovision of wetlands from a benefit-cost or potential Pareto-efficiency standpoint. Increased wetlands valuation resulting from more complete and certain consumer valuation processes may be a desirable effect of additional *SI*.

The results of the *SI* experiment, although consistent with previous studies, must be cautiously interpreted. The additional *SI* presented to recreationists described beneficial consumption services or attributes (as indicated by responses to an on-site preference survey). Wetlands also support consumption services or attributes such as exposure to insects, poisonous snakes, and hungry alligators, which some recreationists may perceive negatively. Additional *SI* which describes negative consumption services or attributes may induce reductions in *WTP* for wetlands protection. Thus, the results of the *SI* experiment do not imply that additional *SI* will always increase *WTP* for an environmental commodity.

Conclusions

Information may be an inportant determinant of perceived values that consumers place upon environmental commodities. Information is also a critical component of contingent valuation studies, but the effects of potential "information biases" are poorly understood. In this paper, a theoretical model of the effects of service information on rationed environmental commodity valuations was developed. *SI* describes consumption services or attributes which can be derived from a given environmental commodity with fixed, objectively measurable characteristics.

The theoretical model was applied to develop a testable hypothesis concerning the effect of *SI* on the magnitude of willingness to pay (*WTP*) for wetlands protection. This hypothesis was tested using a contingent valuation method (CVM) field survey experiment. The results indicate that *SI* increased *WTP* for wetlands protection. This information effect is argued not to be an undesirable bias. Rather, it is contended that *SI* increased the completeness and accuracy of wetlands protection valuations and therefore induced a desirable information effect. The results, in general, support the argument that information is an important input into consumer valuation decisions.

The *SI* presented to CVM participants described only beneficial consumption services or attributes supported by wetlands. The results may not generalize to situations where additional *SI* may also describe consumption services of attributes that consumers value negatively. A more complete understanding of the effects of specific types of information on consumer valuation decisions requires additional research.

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Appendix

Service Information in Alternative Questionnaire Versions

Version A (No Explicit Service Information)
In the study wetland area, however, management programs could be carried out to reduce the rate of marsh loss. By reducing marsh loss, such programs would help to preserve populations of waterfowl, freshwater fish, saltwater fish, shrimp, and crabs in the study wetland area.
Version B (Explicit Service Information)
In the study wetland area, however, management programs could be carried out to reduce the rate of marsh loss. By reducing marsh loss, such programs would help to preserve populations of waterfowl, freshwater fish, saltwater fish, shrimp, and crabs in the study wetland area. Preservation of waterfowl, freshwater fish, saltwater fish, shrimp, and crab populations would help to protect your bag or catch of these species. Reduced marsh loss would also help to preserve other attributes of wetlands which you may value; for example: opportunities for viewing wildlife, marsh scenery, and isolated or remote areas where you can experience the outdoors.[a]

[a] To simplify and reduce wording, the phrase "attributes of wetlands" was used to represent consumption services or attributes associated with consumption activities produced from wetlands (e.g., recreational trips). The use of this phrase is consistent with the conceptual model, and it is argued that the meaning of the wording was clear to respondents from the context of the paragraph. Respondents were asked to provide feedback on the clarity of the questionnaire wording. None indicated problems understanding the questionnaire, including the service information.

Relative Agricultural Prices and Monetary Policy

John S. Lapp

An imperfect information, rational expectations model of relative price determination is presented. This model provides an econometric specification for testing for a causal relationship between money and the relative prices of agricultural commodities. Test results indicate that variations in the growth rate of the nominal money supply (whether anticipated or unanticipated) have not been an important influence on the average level of prices received by farmers relative to other prices in the economy over the period 1951–85.

Key words: commodity prices, monetary policy, relative prices.

At least since Schuh's 1974 article, interest has continued in the possible effects of monetary policy on agricultural markets. The issue is important because policies to stabilize agricultural markets must consider the sources of volatility in the industry. This paper explores this issue by studying the relationship between the growth rate of the nominal money supply and the relative price of agricultural commodities (defined as the "Index of Prices Received by Farmers" deflated by an aggregate price index). The focus is on relative agricultural prices because theory relates this price variable to issues involving supply, demand, and welfare. Unlike earlier work on this topic, the paper employs a model of the type introduced by Lucas and Barro which assumes market clearing equilibrium and imperfect information about aggregate prices. This model implies that unexpected money growth, but not anticipated money growth, may affect relative agricultural prices.

Empirical evidence indicates that nominal agricultural prices are affected by monetary events (Chambers and Just, Rausser et al., Orden (1986b, Starleaf). This implies short-run relative price effects if prices are sticky in other markets but flexible in agriculture.[1] However, Pauls has shown that relative prices in several supposedly sticky price industries behave as if prices were generally flexible. See Chambers (1984, 1985) for a discussion of the crucial role of the sticky prices assumption in this literature. Explicit tests for monetary effects on relative agricultural prices yield mixed results. Orden (1986b); Starleaf, Meyers, and Womack; and Devadoss and Meyers find evidence for effects on relative agricultural prices.[2] Belongia found small effects of unanticipated inflation on relative agricultural prices. Bessler, Gardner, and Grennes and Lapp, on the other hand, find that relative agricultural prices are not affected by nominal macroeconomic variables.

This paper is organized as follows. The next section develops a model of relative prices and monetary shocks which leads to an empirical specification for hypothesis testing. The third section sets out a strategy for testing for a relationship between money growth and relative agricultural prices. The empirical results are presented in the fourth section. Conclusions are discussed in a final section.

Model

The logic of the model is summarized as follows.[3] Buyers and sellers enter any product market with knowledge of supply and demand con-

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[1] This result derives from the fix price-flex price models discussed by Okun. See Bordo for an application to relative prices. Frankel has formally modeled this for agricultural markets by applying the overshooting phenomenon.

[2] Chambers (1984) finds evidence that money affects a set of three variables including relative agricultural prices, but does not report results for the individual variables.

[3] The following derivation generally follows Hercowitz but incorporates intertemporal substitution, as suggested by Pauls.

ditions and an expectation of the general price level. This implies an expected nominal price for the product. The actual nominal price will generally differ from the expected value due to real and monetary shocks. Because these shocks cannot be individually observed, the monetary shocks may be mistaken for real shocks. If so, the monetary shocks will affect the actual relative price.

Assume that supply and demand conditions in market i are given by

$$(1)\quad y(i)_t^s = \alpha(i)^s[P(i)_t - E(P_t)] + \beta(i)^s E[P(i)_{t+1} - P_{t+1}] + \epsilon(i)_t^s, \text{ and}$$

$$(2)\quad y(i)_t^d = \alpha(i)^d[P(i)_t - E(P_t)] + [M_t - E(P_t)] + \beta(i)^d \cdot E[P(i)_{t+1} - P_{t+1}] + \epsilon(i)_t^d,$$

where $y(i)$ is the quantity sold in market i, $P(i)$ is the market i price, P is the aggregate price level, M is the nominal money supply, E is the expectations operator and $\epsilon(i)^s$ and $\epsilon(i)^d$ are normal, i.i.d. disturbances. All variables are expressed in natural logarithms.

Supply and demand depend on current and expected, future relative prices, reflecting the opportunity for intertemporal substitution. Suppliers can wait until the following period to sell output, or sell from stocks, depending on their relative price expectations. Similarly, demanders can defer or accelerate purchases. The opportunities for intertemporal substitution may be more limited in agriculture than in some other industries. Nonetheless, choices about the timing of slaughter and storage permit some intertemporal substitution on both sides of the market.[4] Thus, $\alpha(i)^s > 0$, $\alpha(i)^d < 0$, $\beta(i)^s < 0$ and $\beta(i)^d > 0$ are assumed. The effects of interest rates and storage costs are not considered. Demand shifts with the real money supply, evaluated at the expected price level, as changes in the real money supply affect aggregate demand and, therefore, the demand for agricultural commodities. This includes exchange rate influences on agricultural markets caused by changes in the real money supply. The unit elasticity for expected real money balances is imposed to facilitate the analysis.

Market participants are assumed to know the nominal price of the commodity, but are uncertain of the aggregate price level. Hence, the relative price is uncertain.

The nominal money supply is represented as

$$(3)\quad M_t = M_{t-1} + g_t + m_t,$$

where g_t is expected, and m_t is unexpected, money growth; m_t is normally distributed with zero mean and variance σ_m^2 and is serially independent.[5]

Solving (1) and (2) for $P(i)_t - E(P_t)$, using the market clearing condition, yields

$$(4)\quad P(i)_t - E(P_t) = \tau(i)\{M_t - E(P_t) + \beta(i)E[P(i)_{t+1} - P_{t+1}] + \epsilon(i)_t\},$$

where $\tau(i) = 1/[\alpha(i)^s - \alpha(i)^d]$, $\beta(i) = \beta(i)^d - \beta(i)^s$, and $\epsilon(i)_t = \epsilon(i)_t^d - \epsilon(i)_t^s$ and is distributed as $N(0, \sigma_i^2)$. Then,

$$(5)\quad P(i)_t = [1 - \tau(i)]E(P_t) + \tau(i)(M_t + \epsilon(i)_t) + \tau(i)\beta(i)E[P(i)_{t+1} - P_{t+1}].$$

Equation (5) is usefully rewritten, using (3), as

$$(5')\quad P(i)_t = [1 - \tau(i)]E(P_t) + \tau(i)(M_{t-1} + g_t + m_t + \epsilon(i)_t) + \tau(i)\beta(i)E[P(i)_{t+1} - P_{t+1}].$$

Market participants are assumed to know the terms in (5′) except for m_t and $\epsilon(i)_t$. Therefore, the observation of $P(i)_t$ permits market participants to deduce $(m_t + \epsilon(i)_t)$, but not m_t or $\epsilon(i)_t$ individually. If sufficient information were available, market participants would only react to $\epsilon(i)_t$. Since $\epsilon(i)_t$ cannot be identified, market participants may erroneously react to m_t as if it were a real shock.

This process is modeled as a revision of $E(P_t)$ conditional on the observed $P(i)_t$. The value of the observed nominal price relative to the conditional expectation of the aggregate price level is the current, expected relative price in (1) and (2). The revision of $E(P_t)$ is based on the portion of $(\epsilon(i)_t + m_t)$ that is attributed to m_t. Since the portion of $(\epsilon(i)_t + m_t)$ that is due to each component is unknown, statistical methods are used to apportion the observed joint shock between the two components. The optimal expectation of m_t, i.e., the mean of the distribution conditional on the observed $P(i)_t$, is

$$(6)\quad E(m_t) = [\sigma_m^2/(\sigma_m^2 + \sigma_i^2)](m_t + \epsilon(i)_t).$$

[4] This model reflects the time at which produce is sold. Therefore, the nominal market price is observable. An alternative viewpoint would be earlier in the production process when the nominal price is not observable. Decisions made at the earlier time have implications for the supply and demand equations assumed here. However, these implications are not treated in this paper.

[5] For the current problem the process generating g_t and m_t need not be specified. Assuming that economic agents enter each period with an expectation of money growth, g_t, is sufficient. Empirical proxies for g_t and m_t are presented below.

As the uncertainity associated with money (σ_m^2) is larger relative to σ_i^2, more of $(\epsilon(i)_t + m_t)$ is attributed to a money growth shock and less to a real shock.

Market participants are assumed to know σ_m^2, σ_i^2 and $(m_t + \epsilon(i)_t)$ and to use this information to revise the expectation of P_t. It is a straightforward, but lengthy, matter to show (see Hercowitz, pp. 333–34) that

$$(7) \quad E(P_t) = M_{t-1} + g_t + [\sigma_m^2/(\sigma_m^2 + (1/\tau)\sigma_i^2)](m_t + \epsilon(i)_t),$$

where τ is the average value of $\tau(i)$ across all markets. Then, using (7) and (5′),

$$(8) \quad P(i)_t = M_{t-1} + g_t + \{[1 - \tau(i)]\Theta(i) + \tau(i)\} \cdot (m_t + \epsilon(i)_t) + \tau(i)\beta(i)E[P(i)_{t+1} - P_{t+1}],$$

where $\Theta(i) = [\sigma_m^2/(\sigma_m^2 + (1/\tau)\sigma_i^2)]$.

Averaging (8) across all markets yields the aggregate price level,

$$(9) \quad P_t = M_{t-1} + g_t + [(1 - \tau)\Theta + \tau]m_t,$$

where Θ is the average, value of $\Theta(i)$ across all markets.[6]

Equations (8) and (9) give the equilibrium values of $P(i)_t$ and P_t that are observed, *ex post*. Subtracting (9) from (8) yields the observed, equilibrium relative price of commodity i,

$$(10) \quad P(i)_t - P_t = \tau(i)\beta(i)E[P(i)_{t+1} - P_{t+1}] + (1 - \Theta(i))[\tau(i) - \tau]m_t + \{[1 - \tau(i)]\Theta(i) + \tau(i)\}\epsilon(i)_t.$$

In general, the relative price in market i depends on the current money growth shock. The sign on m_t is unknown because $[\tau(i) - \tau]$ depends on market-specific supply and demand elasticities. The sign must vary across markets because all relative prices cannot move in the same direction.

The remaining issue is to develop a proxy for $E[P(i)_{t+1} - P_{t+1}]$. Presumably, economic agents base this expectation on industry-specific knowledge that is not observable to the analyst. Pauls provides the necessary proxy by assuming that

$$(11) \quad E[P(i)_{t+1} - P_{t+1}] = A_1(L)[y(i)_{t-1} - y_{t-1}] + A_2(L)[P(i)_{t-1} - P_{t-1}],$$

where $y(i)$ and y are output in market i and in the aggregate, respectively, and $A_1(L)$ and $A_2(L)$ are polynomials in the lag operator. The real factors affecting any market in a given period will be reflected in the relative price and quantity in that market. If these real factors or their effects are serially correlated, the relative prices and quantities in one period contain information that is relevant for predicting relative prices in later periods. Moreover, anticipated future supply and demand factors will affect relative prices and quantities in the periods when those anticipations are formed. Based on these relationships, lagged values of relative prices and quantities reflect information that is the basis for expectations of future relative prices. Including quantities in (11) adds information that is not captured by relative prices alone since, in principle, including quantities would allow demand and supply shifters to be identified. Quantities are expressed relative to aggregate output to correct for scale effects over time. Pauls cites the Hansen and Sargent modeling of dynamics in a rational expectations framework in support of this approach.

Substituting (11) into (10) and setting $i = a$ to specify the market for agricultural commodities, yields the following equation for the relative price of agricultural commodities

$$(12) \quad P(a)_t - P_t = \tau(a)\beta(a)\{A_1(L) \cdot [y(a)_{t-1} - y_{t-1}] + A_2(L)[P(a)_{t-1} - P_{t-1}]\} + (1 - \Theta(a))[\tau(a) - \tau]m_t + \{[1 - \tau(a)]\,\Theta(a) + \tau(a)\}\epsilon(a)_t.$$

Equation (12) implies that the relative price of agricultural commodities may be correlated with the contemporaneous monetary shocks, m_t if $[\tau(a) - \tau]$ is nonzero. If supply and demand in agricultural markets are less elastic than average, as is usually expected, the sign of $(1 - \Theta(a))[\tau(a) - \tau]$ will be positive.[7] This equation also implies that relative agricultural prices are independent of past monetary growth rates and the anticipated component of money growth. These factors are not mistaken for real shocks and, therefore, do not affect supply or demand.

From the definition of $\Theta(a)$, the coefficient on m_t is related to the variance of unexpected money growth, σ_m^2, because greater uncertainty about money growth decreases the extent to which real market shocks are inferred from observations on nominal market prices.

[6] $\epsilon(i)_t$ drops out of (8) since its average value, across all markets, is zero. The last term of (8) disappears since the average $P(i)$, for any period, is P.

[7] The author is indebted to a reviewer for this insight. The estimated coefficients for m_t reported below are positive.

Empirical Tests

The empirical sections of this paper present tests for a statistically significant relationship between money growth and relative agricultural prices.[8] The form of the equations to be estimated is given by (12), rewritten as

$$(13)\quad P(a)_t - P_t = a_0 + \sum_{k=1}^{N} [a_k(P(a) - P)_{t-k} + b_k(y(a) - y)_{t-k}] + \sum_{j=0}^{T} [c_j\mu_{t-j} + d_j\mu_{t-j}\sigma_{\mu t-j}] + \epsilon_t.$$

The variable μ represents actual money growth or any of three alternative measures of anticipated and unanticipated money growth as defined below. The standard deviation of unanticipated money growth is σ_μ. Initially the d_j were constrained to zero.

These equations were estimated using quarterly data for the period 1951–85. The relative prices of agricultural commodities were measured by the "Index of Prices Received by Farmers" deflated by (*a*) the consumer price index (CPI), and (*b*) the producer price index (PPI). The relative output of agricultural commodities was measured by real GDP for the farm sector relative to total real GDP. The *M*1 definition of the money supply was used.

Expected and unexpected money growth must be defined. Since there is no way to know if an appropriate measure of anticipated money growth has been used, three different definitions were employed, each derived by a different method. It is assumed that expectations of money growth are formed for one quarter ahead and that expectations with a longer horizon are not formed.

The money growth variables used for estimation are as follows: *MU*, The actual, annualized, quarterly growth rate; *MUS*1, The residual from an estimated Box-Jenkins "Airline Model" ARMA process (which includes AR terms at the seasonal lags) for the quarterly growth rate of the money supply;[9] *MUX*1, *MU* minus *MUS*1; *MUS*2, the difference between the actual money growth rate and the bond-equivalent yield on 3-month treasury bills maturing at the end of the quarter;[10] *MUX*2, *MU* minus *MUS*2; *MUS*3, The residual from a regression of *MU* on lagged value of *MU*, lagged inflation rates and lagged unemployment rates;[11] *MUX*3, *MU* minus *MUS*3. *MUS*1, *MUS*2, and *MUS*3 are alternative measures of unexpected money growth shocks. *MUX*1, *MUX*2 and *MUX*3 are the corresponding measures of expected money growth.[12] The *MUS*1 and *MUS*3 measures meet the requirement of being white noise residuals. The theory predicts that any relationship between relative prices and money growth will be found in the variables *MUS*1, *MUS*2, or *MUS*3, not in *MUX*1, *MUX*2, or *MUX*3. *MU* was included among the specifications for generality.

Equation (13) does not directly control for real factors affecting agricultural markets. However, to the extent that these factors or their effects are serially correlated, they are captured in the lagged values of relative prices and quantities. Otherwise, they constitute the error term.

The theory applies to contemporaneous money growth shocks but cannot determine the length of the contemporaneous period. Because the appropriate length of a period may be longer than a quarter, a variety of lag lengths were considered. Short lags on *MUS*1, *MUS*2, or *MUS*3 would be consistent with the model; long lags would not. The lag lengths are defined in (13) by the parameters *N* and *T*. Because these tests can be sensitive to lag lengths (Saunders), they were based on the values 4, 8, and 12 for *N* and 0, 1, 2, 3, 4, 8, and 12 for *T*. The results for $N = 8$ and $N = 12$ are the same as the results for $N = 4$ except that the significance levels are lower. Only the results for $N = 4$ are reported below. Tests based on $T = 8$ and $T = 12$ never showed significant results and are not reported below.[13]

The relative prices of agricultural commodities have a distinct downward trend over the

[8] All data are from CITIBASE except for the nominal money supply for 1947: 1-1958:4, which is from the Federal Reserve Bank of St. Louis and the "Index of Prices Received by Farmers" prior to 1965:1, which are from *Agricultural Prices, Annual Summary*, various years, USDA, Washington DC. Estimates were computed using SHAZAM (White).

[9] This measure of unanticipated money growth is based on the assumption that economic agents try to extrapolate past patterns of money growth in forming expectations of future money growth.

[10] This market-based measure of unexpected money growth requires a constant trend rate of growth of the velocity of money (Levi and Shapiro). Hence, the sample period was terminated at 1981:4 for tests involving this measure.

[11] This measure assumes that economic agents predict money growth on the basis of the Fed's likely reaction to important macroeconomic variables. The lag length was nine quarters, which minimized the Akaike final prediction error.

[12] Tests based on a two-step estimation procedure have been criticized as inefficient (Mishkin). However, joint estimation is not practical here because the moving standard deviation of unexpected money growth is used as a measure of $\sigma\mu$. Therefore, *MUS*2 was used as an alternative measure.

[13] Results for $N = 8$, 12 and $T = 8$, 12 are available from the author.

Table 1. Test Statistics for Equation (13) for Alternative Measures of Money Growth and Price Deflators

	First Period		Second Period	
Deflator:	CPI	PPI	CPI	PPI
Serial Correlation Tests				
Durbin's *m*	F(4,67)[a]	F(4,67)	F(4,38)	F(4,38)
MU	1.08	1.40	1.93	2.12
			F(4,34)	F(4,34)
*MUS*1	1.03	1.69	0.66	0.95
*MUX*1	1.22	1.03	1.21	1.80
			F(4,18)	F(4,18)
*MUS*2	1.04	1.23	1.53	2.07
*MUX*2	0.93	0.83	0.87	1.45
			F(4,38)	F(4,38)
*MUS*3	1.20	1.03	1.22	2.35
*MUX*3	1.12	1.19	1.07	2.39
Box-Pierce-Ljung	Q(23)	Q(23)	Q(17)	Q(17)
MU	16.89	17.78	8.99	10.81
			Q(16)	Q(16)
*MUS*1	15.90	15.70	10.05	11.28
*MUX*1	16.87	17.00	7.75	9.22
			Q(11)	Q(11)
*MUS*2	16.94	17.85	5.25	6.63
*MUX*2	17.25	17.28	4.84	6.35
			Q(17)	Q(17)
*MUS*3	17.37	17.86	10.91	10.89
*MUX*3	16.69	17.71	10.16	11.94
Lagrange Multiplier Test for Normality, Chi-Square (2)				
MU	2.41	2.37	0.39	0.81
*MUS*1	3.01	2.81	0.40	0.65
*MUX*1	3.09	2.99	0.16	0.53
*MUS*2	2.26	2.18	0.25	0.16
*MUX*2	1.67	1.42	0.41	0.46
*MUS*3	2.72	2.45	1.41	1.17
*MUX*3	2.66	2.63	1.10	0.96
Goodness-of-Fit Tests				
Regression *F*	F(12,75)	F(12,75)	F(10,45)	F(10,45)
MU	2.84**[b]	2.08*	2.79**	1.97
			F(10,41)	F(10,41)
*MUS*1	3.02**	2.21*	2.90**	2.08*
*MUX*1	2.83**	2.10*	2.63*	1.87
			F(10,25)	F(10,25)
*MUS*2	2.87**	2.10*	2.36*	1.88
*MUX*2	3.14**	2.45*	2.44*	1.91
			F(10,45)	F(10,45)
*MUS*3	2.83**	2.09*	2.01	1.98
*MUX*3	2.82**	2.07*	1.96	2.01
Regression R^2				
MU	0.31	0.25	0.38	0.30
*MUS*1	0.33	0.26	0.41	0.34
*MUX*1	0.31	0.25	0.39	0.31
*MUS*2	0.31	0.25	0.31	0.43
*MUX*2	0.33	0.28	0.49	0.43
*MUS*3	0.31	0.25	0.31	0.31
*MUX*3	0.31	0.25	0.30	0.31

[a] Degrees of freedom are given in parentheses.
[b] Single asterisk indicates significance at 5% level; double asterisk indicates significance at 1% level.

sample period. Consequently, the variables were first differenced for stationarity. A dummy variable, equal to 1 for each quarter in 1973 and 0 otherwise, was included to control for the atypical volatility in 1973.

The tests in this paper are t- and F-tests of the hypotheses that the c_j and d_j of (13) are individually or jointly zero. To use the t- and F-tests the disturbances must have a normal distribution and serial independence. Therefore, the regression residuals were subjected to the Jarque-Bera Lagrange Multiplier test for normality and Durbin's h, Durbin's m, and the Box-Pierce-Ljung Q tests for serial correlation.[14] Estimation of (13) using the full period as a single sample did not pass these tests for either normality or serial independence. However, when the sample was split after 1972:4, equations with well-behaved residuals were estimated separately for each subperiod. This break point was based on a plot of the dependent variable. A disruption in commodity markets, the emergence of OPEC, a change in the operation of price supports in agriculture and the general conversion to floating exchange rates all occurred in 1973. Thus, the period beginning in 1973 differed substantially from the preceding period.

F-tests showed that seasonal factors were important in the earlier period, but not for the later period. Hence, seasonal dummy variables were included in regressions for the earlier period.

Empirical Results

Table 1 reports results for tests of serial correlation, normality, and goodness-of-fit for $T = 0$, $N = 4$. The results indicate that the model explains about 30% and, in some cases more, of the variation in the relative price of agricultural commodities (first differenced). The residuals are well-behaved and the F-ratios are generally significant.[15]

Table 2 presents the results of testing for monetary effects for alternative money growth variables, alternative values of T and both price deflators for $N = 4$. The entries are F-ratios for

Table 2. F-Tests on Alternative Measures of Money Growth for Various Lag Lengths

	First Period		Second Period	
Deflator	CPI	PPI	CPI	PPI
$T = 0$	$F(1,75)$[a]	$F(1,75)$	$F(1,45)$	$F(1,45)$
MU	0.30	0.07	0.04	0.06
			$F(1,41)$	$F(1,41)$
*MUS*1	1.74	1.19	1.77	1.49
*MUX*1	0.14	0.21	0.12	0.07
			$F(1,25)$	$F(1,25)$
*MUS*2	0.50	0.21	0.25	0.42
*MUX*2	2.74	3.38	0.66	0.56
			$F(1,45)$	$F(1,45)$
*MUS*3	0.15	0.16	0.40	0.12
*MUX*3	0.07	0.00	0.03	0.33
$T = 1$	$F(2,74)$	$F(2,74)$	$F(2,44)$	$F(2,44)$
MU	0.86	1.02	0.08	0.04
			$F(2,40)$	$F(2,40)$
*MUS*1	5.39**[b]	5.08**	1.04	1.02
*MUX*1	0.32	0.25	0.06	0.06
			$F(2,24)$	$F(2,24)$
*MUS*2	0.93	1.05	0.14	0.20
*MUX*2	1.41	1.73	0.34	0.34
			$F(2,44)$	$F(2,44)$
*MUS*3	0.42	0.39	0.52	0.59
*MUX*3	0.27	0.44	1.09	0.83
$T = 2$	$F(3,73)$	$F(3,73)$	$F(3,43)$	$F(3,43)$
MU	0.90	0.89	0.19	0.28
			$F(3,39)$	$F(3,39)$
*MUS*1	3.70*	3.40*	0.69	0.70
*MUX*1	0.29	0.23	0.13	0.15
			$F(3,23)$	$F(3,23)$
*MUS*2	0.96	0.92	0.09	0.18
*MUX*2	1.02	1.20	0.30	0.23
			$F(3,43)$	$F(3,43)$
*MUS*3	0.31	0.29	0.34	0.40
*MUX*3	0.37	0.38	0.72	0.83
$T = 3$	$F(4,72)$	$F(4,72)$	$F(4,42)$	$F(4,42)$
MU	1.15	1.19	0.51	0.45
			$F(4,38)$	$F(4,38)$
*MUS*1	2.78*	2.52*	1.05	0.80
*MUX*1	0.32	0.26	0.91	0.63
			$F(4,22)$	$F(4,22)$
*MUS*2	1.16	1.15	0.24	0.18
*MUX*2	0.80	0.92	0.22	0.17
			$F(4,42)$	$F(4,42)$
*MUS*3	0.28	0.30	0.30	0.3.1
*MUX*3	0.34	0.34	0.88	0.94
$T = 4$	$F(5,71)$	$F(5,71)$	$F(5,41)$	$F(5,41)$
MU	0.91	0.96	0.42	0.44
			$F(5,37)$	$F(5,37)$
*MUS*1	2.19	2.01	1.15	0.87
*MUX*1	0.26	0.22	0.81	0.60
			$F(5,21)$	$F(5,21)$
*MUS*2	0.92	0.93	0.23	0.25
*MUX*2	0.83	0.82	0.27	0.32
			$F(5,41)$	$F(5,41)$
*MUS*3	0.26	0.25	0.28	0.24
*MUX*3	0.29	0.30	0.76	1.12

[a] Degrees of freedom are given in parentheses.
[b] Single asterisk indicates significance at 5% level; double asterisk indicates significance at 1% level.

[14] Durbin's m, the Q-test and the Lagrange Multiplier test for normality are described in Kmenta, pages 266, 332, and 333, respectively. In many cases Durbin's h-statistic could not be computed.

[15] However, the estimated equations for the second period with $N = 8$ and 12 generally have insignificant regression F-ratios. Durbin's h indicates serial correlation for one of the specifications with $N = 12$ in the second period.

Table 3. Estimated Coefficients on Money Growth for Specifications with Significant F-Ratios in Table 2

	CPI				PPI			
Deflator:	c_0	c_1	c_2	c_3	c_0	c_1	c_2	c_3
$T = 1$	0.16*	0.21**			0.13*	0.19**		
$t(74)^a =$	2.21	2.98			1.98	2.97		
$T = 2$	0.14	0.19*	−0.05		0.13	0.18*	−0.3	
$t(73) =$	1.87	2.41	−0.63		1.75	2.51	−0.38	
$T = 3$	0.13	0.17	−0.07	−0.04	0.12	0.18*	−0.04	−0.01
$t(72) =$	1.51	1.91	−0.75	−0.40	1.49	2.11	−0.41	−0.17

[a] Degrees of freedom are given in parentheses.
[b] Single asterisk indicates significance at 5% level; double asterisk indicates significance at 1% level.

the hypothesis $c_0 = \ldots = c_T = 0$ in (13). None of the F-ratios in these tables indicate a significant relationship between relative agricultural prices and actual money growth or any of the measures of expected money growth. A statistically significant relationship between relative agricultural prices (using either definition) and unanticipated money growth is suggested for $MUS1$, but not $MUS2$ or $MUS3$, in the first period for the short lag lengths. There is no evidence of a significant relationship between any of the money growth variables and the dependent variables for the second period.

Table 3 shows the coefficient estimates and their t-ratios for contemporaneous and lagged $MUS1$ for the significant specifications in table 2. These estimates show that an unexpected money growth shock had a positive effect on the relative price of agricultural commodities for the period before 1973. This direct effect appears to have persisted for two quarters. Given the lagged values of the dependent variable on the right-hand side, monetary shocks had persistent indirect effects. Based on the Akaike final prediction error criterion the optimal lag length for lagged relative prices was four quarters. The sums of the estimated coefficients on lagged relative prices are less than 0.3. Hence, the indirect effects of money growth shocks are small and die out quickly.

The economic significance of these effects can be considered in two ways: (a) by considering the estimated effect of a representative money growth shock on relative agricultural prices, and (b) by considering the effects of money growth shocks on the explanatory power of the regression equations. Using the coefficient estimates from the first row of table 3, consider a positive money growth shock equal to one standard deviation of $MUS1$. The direct effect of the shock would cause the relative price of agricultural commodities (using the CPI as the deflator) to be increased by 0.0027 in the quarter in which the shock occurred and by 0.0036 in the following quarter. This compares to an average value during this period of 0.6075 and a standard deviation of 0.0838. That is, the response to a money growth shock equal to one standard deviation of unexpected money growth is less than one-tenth of the standard deviation of relative agricultural prices.

Table 4 presents adjusted R^2 values for those specifications in table 2 with significant F-ratios and for specifications containing no money growth variables. The inclusion of contemporaneous and lagged $MUS1$ provides a modest, yet statistically significant, increase in the explained variation in the relative prices of agricultural commodities. However, money growth shocks account for a negligible fraction of the variation in the relative prices of agricultural commodities.

Equation (13) was estimated without constraining the d_j to zero to consider the effect of the variability of money growth. Moving stan-

Table 4. Adjusted R-Squared Values for Specifications with Significant F-Ratios in Table 2 and for Specifications without Money Growth

Deflator:	CPI	PPI
$T = 1$	0.29	0.22
$T = 2$	0.29	0.21
$T = 3$	0.28	0.20
$c_j = 0$, all j	0.21	0.14

dard deviations were calculated as measures of σ_μ for each of the measures of unexpected money growth. F-tests of the hypothesis $c_0 = c_1 = d_0$ $d_1 = 0$ were computed for $N = 4$ and $T = 1$ for each definition of relative prices and each time period. All of the F-ratios were insignificant.

Conclusions

According to the empirical results in this paper, monetary policy has not been a quantitatively important determinant of relative agricultural prices. A statistically significant relationship between money growth and relative agricultural prices was found only for one of three measures of unexpected money growth and only for the period before 1973. No significant relationship was found for actual money growth, for expected money growth, or for the standard deviation of unexpected money growth.

The single significant relationship indicated a transitory, positive impact of unexpected money growth on the relative price of agricultural commodities. The estimated effect is quantitatively small and does not explain an economically meaningful portion of the variation in the relative price of agricultural commodities.

For the period after 1972, no relationship is indicated. The finding of independence of relative agricultural prices from monetary disturbances is consistent with recent findings by Kretzmer. He reports finding real effects from money shocks in a variety of industries, but not in the agriculture, forestry, and fisheries industry.

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A Policy Preference Function for Government Intervention in the U.S. Wheat Market

James F. Oehmke and Xianbin Yao

This paper estimates a policy preference function that explains the government's choices of target prices, government held wheat stocks, and public wheat research funding. The policy preference function depends on producers' surplus, consumers' surplus, and budget expenditures. An important innovation in this paper is the inclusion of interactions between public research expenditures and other public policy variables. Results indicate that the government places a premium of 25% to 45% on the welfare of wheat producers of relative to budget expenditures, while wheat consumers' welfare is discounted as much as 50% relative to budget expenditures.

Key words: agricultural research, policy preference function, wheat.

The purpose of this paper is to provide an explanation of government commodity programs, stock accumulations, and research expenditures in the U.S. wheat sector. The explanation is based on a policy preference function (PPF) that depends on producers' surplus, consumers' surplus, and budget expenditures. It is assumed that target prices, reductions in (or additions to) government stocks, and public research expenditures are chosen to maximize the policy preference function. The central contribution of the paper is the estimation of a function that is consistent with the observed government interventions in the U.S. wheat market. That is, the paper explains the observed target prices, government sales, and public research expenditures as rational behavior by a government which seeks to maximize the estimated policy preference function.

The approach in this paper is based on the political interest group theories of Peltzman and Becker. Applications of these ideas to agriculture include Rausser and Freebairn's description of the beef industry, Gardner's (1985) analysis of commodity price programs and his simulation of optimal agricultural research expenditures (Gardner 1987), Pashigian's explanation of futures trading restrictions, and Chou's international political interest group model. The major innovation here is the explicit modeling of interactions between research and other government interventions in a simple dynamic framework. Previous explanations of research support have generally ignored the effects of nonresearch government policy (e.g., Evenson, Waggoner, and Ruttan; Ruttan; Oehmke).

The remainder of the paper is organized as follows. The next three sections describe the rationale behind the policy preference function, specify the functional form of the PPF, and introduce the policy instruments of public research funding, commodity programs, and changes in government stocks. The effects of these instruments on market variables and on the components of the government PPF are analyzed. The model then is applied to the U.S. wheat sector.

The Political Decision-Making Process

Peltzman and Becker (1983, 1974) model the political decision process as a set of interactions between the actors affected by potential government policies and the administering agencies.

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We call the administering agencies "the government," and the other agents are called "interest groups" (IGs). The interactions between the government and the IGs result in a particular set of policies. The set of policies is determined by the pressures of various IGs and the government's responses to these pressures. These pressures and responses will be determined in part by the size of the group, the transactions costs within the group, total benefits per member from the potential policy, the distribution of benefits within the group, and the costs of influencing the government. The relationships among the IGs will also be important: individuals may be members of more than one IG, e.g., farmers and consumers; interest groups may have complementary purposes, e.g., corn producers and soybean producers; the groups may directly oppose each other, e.g., dairy and beef producers on the dairy termination program; or groups with similar interests may have trouble working together, e.g., California and Minnesota dairy producers on the regulation of bovine somatatropin.

The result of these interest group and government interactions is a set of policies that may provide a positive net payoff to some IGs and a negative net payoff to others. Naturally, each interest group desires to receive a positive net payoff but may find it too costly to influence the government effectively. When inefficiencies occur in the transmission of benefits from one group to another, this policy formation process can be thought of as a negative sum game. That is, if government policies have associated deadweight losses, then society faces an overall net decline in economic efficiency (also see the literature on DUPs; e.g., Bhagwati, or Bhagwati and Srinivasan). If part of the transfer is motivated by altruism (Becker 1983, 1974) and if the government makes the transfer efficiently, then the policy formation process can be a positive sum game (Bullock).

The Peltzman-Becker theory of regulation and interest groups leads to empirical models in which the policy instruments and/or the degree of intervention are dependent variables. An important class of models (policy preference function models) focuses on the government agencies making the policy decisions. The PPF models assume that the interest group pressure forces the government to consider a set of criteria that roughly correspond to the desires of the various interest groups; these criteria are then arguments in the government's PPF. Examples of possible criteria are consumers' surplus, producers' surplus, net farm income, net exports, and government budget expenditures. In a PPF model the government chooses the types and degrees of intervention to maximize an objective function dependent on these multiple criteria. The resulting empirical formulation is an equation where the types and degrees of intervention are the dependent variables, and the set of criteria is the set of explanatory variables.

The Policy Preference Function

The policy preference function for the government is

$$V = \sum_{t=0}^{\infty} \beta^t V_t(\Delta CS, \Delta PS, \Delta G), \tag{1}$$

where ΔCS is the change in consumers' surplus, ΔPS is the change in producers' surplus, and ΔG is the change in budget expenditures attributable to the government intervention; V_t is the instantaneous value function representing the governments's preferences at time t; and β is a discount factor. (For a similar but static formulation, see Gardner 1983.) The first two arguments in the objective function are the constituents of any increase in social surplus ($SS = CS + PS$ in an undistorted market), which is a relevant measure of economic efficiency (Currie, Murphy and Schmitz). Consumers' surplus and producers' surplus are treated separately in (1) because the distribution of benefits between consumers and producers may be important to the government. Traditionally, the United States has been willing to redistribute income to farm producers. Equation (1) can capture this objective by placing a relatively high weight on producers' surplus.[1] The third argument in (1) is government expenditures. These are politically and economically important: the economic aspect will be discussed in greater detail below. It is assumed that $\partial V/\partial(\Delta PS) > 0$, $\partial V/\partial(\Delta CS) > 0$, and $\partial V/\partial\ (\Delta G) < 0$. In the special case when $V = \Delta PS + \Delta CS - \Delta G$, the value function approach is equivalent to the standard benefit-cost analysis of public policies (Harberger, Gittinger, Akino and Hayami).

The government's policy instruments are expressed in a commodity program that includes a target price, P_t, changes in government-owned

[1] Formally, we would expect that $\partial V/\partial(\Delta PS) > \partial V/\partial(\Delta CS)$ in a neighborhood of the no-intervention equilibrium.

stocks, Z_t, and a public research program with expenditures of R_t. These policy instruments affect CS, PS, and G. The choices of P_t, Z_t, and R_t are made to maximize V. Other types of government interventions such as lump-sum transfers or export subsidies that were infrequently used during the sample period (1978–85) are not considered.[2]

The solutions to (1) are referred to as the "policy optimal" target price, changes in government stocks, and public research funding levels. This nomenclature will distinguish these levels from the economically efficient levels, which the literature often refers to as the "optimal" levels.

The Policy Tools

This section presents a partial equilibrium model of a competitive, international market for a single agricultural good that is affected by the policy tools of publicly sponsored research, target prices, and sales from government stocks (for similar models, see Carter or Rodgers).

The agricultural markets are depicted in figure 1. Panel *a* represents the U.S. market for the agricultural output and panel *b* represents the world market. In panel *a* curves *D* and *S* are the domestic demand and supply curves that would occur without government intervention. In the world market the *ES* curve is the difference between the U.S. supply and demand curves; it represents the excess supply in the United States or, equivalently, it represents the supply of exports from the U.S. private sector to the rest of the world (ROW). The *ED* curve represents the excess demand by the ROW. In the absence of government intervention, the equilibrium will occur at the world price P_{w0} satisfying $ED(P_{w0}) = ES(P_{w0})$.

These supply and demand curves represent an intermediate-run scenario. The supply curve is considered a preplanting supply curve: the farmer still must make this year's production decisions, but available land, buildings, and to some extent equipment, are fixed.

The first policy instrument is a publicly funded research program that reduces production costs throughout the relevant range. The second policy instrument is a commodity program that includes a target price with a subsidiary loan rate set at or below the market price and an acreage set-aside requirement for participation in the

[2] For a discussion of the choice of policy instruments see Paarlberg (1984, 1985), Gardner (1983, 1985) and Orden.

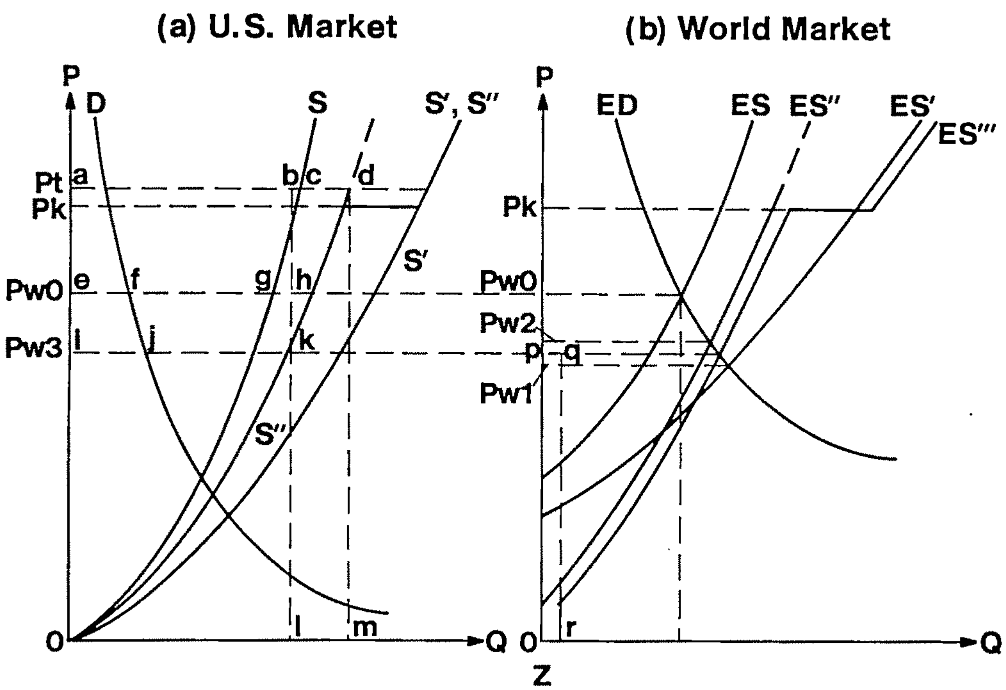

Figure 1. The effects of interventions on the agricultural markets

program. The target price in effect guarantees to domestic producers an amount equal to the target price for each unit produced on program acreage. Farmers are assumed to sell first to the market at the world price and then to the government at the loan rate. The government then makes up, through deficiency payments, any difference between the market price or loan rate and the target price. The cost of the commodity program includes the cost of the loans made to farmers plus the deficiency payments. The government can choose to reduce the stocks accumulated through the commodity program by selling grain on the world market. The third government policy instrument is the sale of grain from stocks.

Public research reduces production costs so that the supply curve S shifts to S'. The excess supply schedule ES' is derived by subtracting the demand curve from the shifted supply curve: $ES'(P) = S'(P) - D(P)$, and consequently ES' shifts to the right as S' does. The equilibrium world price falls from P_{w0} to P_{w1}.

The acreage set-aside requirement reduces output at all prices less than P_k by a proportion h. For these prices the supply curve S shifts back to the left, as represented by the supply curve S''. Figure 1 represents a net government intervention effect in which the supply curve shifts to the right, from S to S'', representing a decrease in production costs (the research effect dominates). Thus, world price P_{w2} is lower than P_{w0}.

The target price supports U.S. producer prices at level P_t. For market prices sufficiently below P_t, domestic supply will always equal the quantity $S''(P_t)$ because P_t is the price relevant to the farmers' decisions. At some market price near P_t, say P_k, farmers (with perfect foresight) will not enroll in the commodity program and thus will not be subject to acreage restrictions. These considerations lead to a kink in the supply curve S'' at P_k, as farmers shift from the acreage-constrained production to the unconstrained production represented by the supply curve S'. In figure 1 this kink is depicted by the horizontal segment of S'' at price P_k. At prices above P_k, the curves S' and S'' coincide. The corresponding kink in the excess supply schedule ES'' is depicted by a horizontal segment at price P_k, and for prices above P_k the ES' and ES'' curves coincide.

Government sales from stocks of amount Z augment the excess supply arising in the private sector. In figure 1 the augmented excess supply curve is represented by $ES''' = ES'' + Z$. Thus, the net effect of all the policy interventions is to shift domestic supply from S to S'', excess supply from ES to ES''', and to change the world price from P_{w0} to P_{w3}.

The effect of government policies on the value of the PPF is explored by examining the effect of the policies on the components of the PPF: consumers' surplus, producers' surplus, and budget expenditures. Domestic consumers' surplus increases due to the lower world price. The amount of the increase is represented by the area *efji*. Producers' surplus increases because of the shift in the supply curve from S to S'' and the higher (target) price received by producers. In figure 1 area *acge* represents increases solely because of the target price program, area *Ogh* represents increases resulting only from supply shifts, and area *cdhg* represents increases attributable to interactions between the supply shifts and the target prices.

Government budget outlays equal the sum of target price and loan and research expenditures less revenues from reduction of grain stocks. Expenditures on target prices and loan rates include payments of $P_t - P_{w3}$ on the amount $S''(P_{w3})$ of grain supplied to the market plus the loan and deficiency payment costs of the excess production $S''(P_t) - S(P_{w3})$. These two costs are represented in figure 1 by the areas *abki* and *bdml*, respectively. Public research expenditures of amount R_0 are not depicted in figure 1; however, they could be inferred from the size of the supply shift and the research production function. Revenues from the reduction of government stocks are represented by area *Opqr* in panel *b* of figure 1.

U.S. Intervention in the Wheat Market

This section illustrates a possible PPF based on U.S. wheat production. It is not an attempt to provide a detailed model of the wheat market: several such models already exist (e.g., Salathe and Langely). Nor is it an attempt to estimate rates of return to research. Only a crude approximation to the dynamics necessary for such an endeavor is used. However, the model sheds light on the political preference function, illustrates the value that the government places on increases in producers' surplus relative to budget expenditures and consumers' surplus, and allows for an informative examination of the interaction between policy instruments.

Assume two periods, 1977 and 1985, and that V has the linear form

$$(2) \quad V = w_1 \cdot \Delta CS_0 + w_2 \cdot \Delta PS_0 - w_3 \cdot \Delta G_0 + w_4 \cdot \Delta CS_1 + w_5 \cdot \Delta PS_1 - w_6 \cdot \Delta G_1.$$

The eight-year difference between the two time periods is chosen because this is an appropriate time lag between the funding of the research budget and the resulting shift in the supply curve (Zentner and Peterson, Norton). The w's represent the weights placed on each policy criterion.

The government is assumed to behave as if it maximizes the *PPF* (2) by choosing research expenditures R_0, target prices P_0 and P_1, and sales from government stocks Z_0 and Z_1. This assumption does not imply that the government is a single actor with underlying, structural preferences represented by (2); rather, it implies that the complex interactions between and among the government agencies and interest groups lead to a reduced-form representation similar to that derived from maximizing (2). For the two period model the relevant first-order conditions are

$$(3) \quad \partial V/\partial P_{t0} = 0 \quad \partial V/\partial P_{t1} = 0$$
$$\partial V/\partial Z_0 = 0 \quad \partial V/\partial Z_1 = 0$$
$$\partial V/\partial R_0 = 0.$$

Because the government knows the weights w_i, it acts as if it solves (3) to determine the optimal levels of policy intervention.

The econometrician's job is to use *ex post* observations on actual government behavior to infer the values of the government weights. For this exercise it is important to note that only relative weights matter, and hence the w's can be normalized by

$$(4) \quad w_3 = 1.$$

This indicates that the weight on 1977 expenditures is the *numèraire,* so that the values of the w_i for $i \neq 3$ represent the weight that the government places on group i relative to the weight it places on budget expenditures. Because the econometrician has observations on actual values of target prices, government sales, and research expenditures, (3) and (4) can be viewed as a system of six equations in the six unknowns $w_1, \ldots, w_6$. Under the usual regularity conditions the implicit function theorem applies, and the system (3) and (4) can be inverted to obtain

$$(5) \quad w_i = w_i(P_{t0}, P_{t1}, Z_0, Z_1, R_0; \text{Market Parameters}).$$

In (5) the phrase "market parameters" refers to the parameters determining the domestic and international supply and demand conditions. The remainder of the paper specifies these parameters and numerically estimates (5).

Assume that the excess demand curve is represented by a constant elasticity equation:

$$(6) \quad ED(P) = kP^{-i}.$$

This specification is consistent with much of the empirical work done on U.S. export elasticities. Based on these studies we specify the value $i = 1.0$. While studies of individual countries usually find much lower absolute elasticities (Abbott, Coffin, Chase-Wilde et al.), one would expect an aggregate absolute elasticity greater than 1 (Bredahl and Gallagher). Schuh suggests that the long-run value may be as high as 2, although this is probably too large (Salathe and Langley).

In the United States, the supply and demand curves are assumed to have constant price elasticity:

$$(7) \quad S(P) = aP^{s}; \quad D(P) = zP^{-e}.$$

It is assumed that $s = 0.4$ and that $e = 0.5$. The value for s is in the middle of the previously estimated elasticities (Salathe and Langley). The estimate for the demand elasticity is a compromise between the relatively low elasticities of food demand and the relatively high elasticities of feed demand (Salathe and Langley). Values for a and z are computed from supply and disappearance quantities, domestic market prices, and target prices; data are found in USDA.

Rewriting *ES* in terms of domestic supply and demand, in the absence of any government intervention the equilibrium condition $ES(P) = ED(P)$ becomes

$$(8) \quad aP_w^{s} - zP_w^{-e} = kP_w^{-i},$$

where P_w is the equilibrium world price.

Research is assumed to shift the parameter a, and the size of the shift is quantified by

$$(9) \quad a = gR^{r},$$

where r is the constant elasticity of supply with respect to research expenditures. While the choice of a functional form for the relationship between supply and research can influence welfare calculations (Lindner and Jarrett), this formulation is consistent with recent empirical work on North

American wheat research (Zentner and Peterson, Norton).[3] We use an elasticity of the supply shift with respect to research of 0.09, which is consistent with Norton's estimates for U.S. cash grain research. However, Norton specifies different lengths of lags between the time that the research is undertaken and the shift in the cost function, with the lags lasting from 0 to 7 years. These lags are shorter than usually found in the literature (Evenson). For example, Zentner and Peterson estimate functional forms that have seven-, eight-, and nine-year lags. Hence, we specify an eight-year lag between the research appropriation and the resulting supply shift.

Equations (6) through (9) specify the market parameters mentioned in equation (5): these market parameters are the parameters of the supply, demand, and research production functions. Exogenous shifts are allowed in the scale parameters a, z, k, and g in order to accommodate the eight-year difference between the two time periods. The magnitude of these shifts is determined from the data (USDA). Parameter values and the imputed values for the exogenous shifts are given in table 1.

Since the equations (6)–(9) specify the relevant market parameters, equation (5) now can be used to infer the government weights.

Results

The estimation results show that wheat producers were weighted more highly than taxpayers, who were weighted more highly than wheat consumers (table 2).[4] The value of 0.46 for w_1 indicates that in 1977 the government was willing to spend a tax dollar to help wheat consumers only if the dollar generated an increase of at least $\$1/0.46 = \$2.17$ in consumers' surplus. However, an investment that generated an increase in producers' surplus of only $\$1/w_2 = \$0.70$ per tax dollar spent was treated as a favorable investment. The weights w_4, w_5, and w_6 estimated for 1985 are slightly less than 1% of the 1977 weights. A pessimist could argue that 1977 policy makers were unconcerned with the future well-being of the population. One explanation is that policy makers were responsive to the desires of their 1977 constituents, who were looking for solutions to immediate problems. Alternatively, one could argue that the administration anticipated at least one and possibly more major pieces of farm legislation between 1977 and 1985, so that the 1985 population would not be greatly affected by the 1977 decisions. This explanation is consistent with the four- to five-year expected duration of most farm bills, in-

[3] These studies use a log-linear cost function in the estimation; this is consistent with a log-linear production function. See Takayama for details.

[4] The weight w_3 is a weight on government expenditures, which could be adjusted by the welfare cost of revenue generation to apply directly to taxpayers. Such an adjustment does not affect the interpretation of the results.

Table 1. Parameter Values Used in Estimation

Items	Notation	Units	1977	1985
Target price	P_t	1977$/bu	2.90	3.66
World price	P_w	1977$/bu	2.33	2.7
Wheat supply at P_t	$S(P_t)$	Million bu	3,160.6	2,834.0
Supply shifter[a,b]	a	Million bu	2,064.5	1,984.2
Domestic demand	$D(P_w)$	Million bu	1,647.0	1,915.6
Demand shifter[a]	z	Million bu	2,410.0	2,929.4
Wheat export	$ED(P_w)$	Million bu	1,123.8	915.4
Export shifter[a]	k	Million bu	2,618.5	2,342.6
Government stocks changes	z	Million bu	1.0	−538.7
Wheat research expenditures	R	Million $	14.581	15.585
Supply elasticity	s	Not applicable	0.40	0.40
Demand elasticity	e	Not applicable	−0.50	−0.50
Export elasticity	i	Not applicable	−1.00	−1.00
Research elasticity	r	Not applicable	0.09	0.09

Sources: Wheat prices, supply, demand, and exports are from the USDA ERS, *Wheat Situation*; wheat research expenditure is from *Inventory of Agricultural Research*.

[a] The figures for shifters are computed from the data in the table; and finally, the figures for elasticities and productivity of research are assumed consistent with the empirical findings in the literature.

[b] The 1985 supply shifter is inclusive of research effects.

Table 2. Estimates of Policy Preference Function Weights, 1977, 1985

w_1	w_2	w_3	w_4	w_5	w_6
0.46	1.43	1.00	0.35×10^{-2}	0.54×10^{-2}	0.42×10^{-2}
			w_4/w_6	w_5/w_6	
			0.81	1.26	

Note: The estimated weights are those values such that the actual research expenditures, target prices and government sales maximize the policy preference function (2).

cluding the Food and Agriculture Act of 1977, which was replaced four years later by the Agriculture and Food Act of 1981.

The relative values w_4/w_6 and w_5/w_6 can be compared to w_1 and w_2 as indicators of changes in the importance of producer or consumer groups from 1977 to 1985. These relative weights are not much different from the 1977 weights, indicating a degree of program consistency over time. However, there are some small changes in the relative weights: the ratios of w_4/w_6 = 0.81 and w_4/w_6 = 1.26 indicate that consumers became more important relative to taxpayers, while the relative importance of producers fell. These changes are consistent with claims that agricultural producer groups lost political power relative to consumer groups during the late 1970s and early 1980s (Hopkins).

The robustness of these results is examined in a sensitivity analysis showing the sensitivity of the estimated PPF weights to the value of the model parameters. The elasticities of the PPF weights with respect to the parameters are presented in table 3. For 1977, the weight on consumers' surplus, w_1, is mildly sensitive to the domestic and international demand parameters e and i. The value of -1.62 for the elasticity with respect to i indicates that a 1% decrease in the elasticity of international demand will lead to a 1.62% increase in the estimated value of w_1. This magnitude is not large enough to change the qualitative results. For example, if the value of i were to fall from 1.0 to 0.8, then the estimated value of w_1 would rise 32% from 0.46 to 0.61, still significantly below the values of w_3 and w_4. The 1985 weights are most sensitive to the parameter h representing the effect of the 1985 land set-aside requirement on the supply curve, probably because that parameter has a huge influence on the budget costs of the target price program (the 1977 wheat program did not have a land diversion clause). The largest elasticity shown in table 3 is that of the weight on producers' surplus in 1985 with respect to h, with a value of 1.81. Nonetheless, this elasticity is not large enough to affect the qualitative results. For example, if the set aside reduced output by only 5% rather than 15%, then the estimate on w_5 would rise from 0.54×10^{-2} to 0.56×10^{-2}. The ratio w_4/w_6 would exhibit the largest change, falling 25% from 0.81 to 0.61. This movement does not affect the qualitative results, nor is it of an unreasonably large magnitude. Thus, the sensitivity analysis presented in table 3 indicates that the estimated weights are reasonably robust to changes in the parameter values.

As a second type of sensitivity analysis, weights were estimated for a 1985 PPF in a one-

Table 3. Elasticities of Weights with Respect to Model Parameters

	Weight[a]				
Parameter	w_1	w_2	w_4	w_5	w_6
s	−0.07	0.03	−0.24	0.19	0.08
e	−1.17	0.00	−0.01	0.63	0.63
i	−1.62	0.00	−0.01	−0.60	0.60
h	−0.00	0.00	−1.39	1.81	1.20
c	0.22	0.02	−0.02	0.08	0.14

Note: w_1 is the weight on consumers' surplus in 1977; w_2 is the weight on producers' surplus in 1977; w_4 is the weight on consumers' surplus in 1985; w_5 is the weight on producers' surplus in 1985; w_6 is the weight on budget expenditures in 1985.
[a] Due to normalization w_3 = 1, the elasticity of this weight is not computed.

period (1985) model, taking previous policy as given. The estimated values maintain the qualitative relationships found in the two-period estimation: producers are weighted more highly than taxpayers, who are weighted more highly than consumers. The weight of consumers relative to taxpayers is approximately the same in 1985 as it was in 1977, but the relative weight on producers declined to 1.25. This weight suggests that $1 spent on producers would have to generate at least an $0.80 increase in producers' surplus in order for the government to find the expenditure worthwhile. These changes correspond to those found between the 1977 and 1985 weights in the two-period estimation. Moreover, the consistency of the relative weights across time suggests that the PPF (2) may be a stable reduced-form representation of the government's decision-making process.

A third sensitivity analysis considers how the government's use of policy instruments changes if the PPF weights change. Because the focus is on how public research expenditures change in response to different government preferences, we utilize the year 1985 in which 1977 research affects production costs. Consider a government which is unwilling to see farmers harmed by policy, including research policy that ultimately leads to a decline in farm prices. This concern can be represented by the constraint $\Delta PS \geq 0$. We then consider the policy preference function,

$$(10) \quad V = w_4 \cdot \Delta CS_{1985} - w_6 \cdot \Delta G_{1985} \quad \text{s.t. } \Delta PS_{1985} \geq 0,$$

and impose the normalization that $w_6 = 1$. The policy-optimal government choices then are determined with respect to the PPF (10).

For the specified values $w_4 = 1.00$ and $w_4 = 0.75$ the results of optimizing (10) are presented in table 4. When the elasticity of supply with respect to research is low ($r = 0.01$) target prices are set 10%–15% higher than the world market price in order to guarantee that $\Delta PS \geq 0$. For $w_4 = 0.75$ policy-optimal research expenditures are $\$20 \times 10^6$, which is approximately equal to the actual expenditures in 1977. The policy-optimal target price is $4.02 per bushel, which is higher than the actual 1985 target price. When the value of the weight w_4 increases to 1.00, the policy-optimal amount of research expenditures increases almost tenfold. This suggests that the policy-optimal amount of research expenditures may be very sensitive to the weight given to future consumers.

When the elasticity of supply with respect to research is relatively high ($r = 0.9$) the policy-optimal research expenditure is around $0.5 billion for either value of w_4. This indicates a sensitivity of research expenditures to the structural, research production parameter r, as would be expected. In this case the size of the supply shift is so great that no target prices are needed to maintain producers' surplus at or above the no-intervention level. This is in part because under this scenario U.S. wheat production has such a huge cost advantage that the U.S. becomes a strongly dominant exporter of wheat on the world market.

If the true research productivity parameter is $r = 0.01$, then the PPF (10) with $w_4 = 0.75$ provides an alternative, rational explanation of government behavior. That is, the policy-opti-

Table 4. Simulated Policy Responses to PPF Weight Changes

	Parameter Values			
	$w_4 = 1.0$		$w_4 = 0.75$	
Variables	$r = 0.9$	$r = 0.01$	$r = 0.9$	$r = 0.01$
Objective function ($\$ \times 10^6$)	3,025	−2,491	2,118	−2,500
World price ($/MT)	23	124.0	26	130.0
Target price ($/MT)	N.A.	141.4	N.A.	148.8
Research expenditures ($R \times 10^6$)	581	190	454	20
Program expenditures ($\$ \times 10^6$)	0	2,010	0	2,063
Total government expenditures ($\$ \times 10^6$)	581	2,201	454	2,083

Note: Modified value function is

$$V = w_4 \cdot \Delta CS - w_6 \Delta G \text{ s.t. } \Delta PS \geq 0.$$

Additional parameter values are $i = 1.5$, $\sigma = 0.6$, $\epsilon = 0.5$. Under both weighting scenarios the commodity program is not necessary to maintain the 1977 level of producers' surplus when $r = 0.9$, so that target prices are not used.

mal target prices and research expenditures under this scenario approximately match observed values.

All of the sensitivity tests indicate that, at least qualitatively, the policy preference function places a high weight on producers' surplus relative to consumers' surplus and budget costs. These results are intuitively plausible and contribute to the validity of the estimated weights.

A detailed examination of the results provides a possible explanation of the observed underfunding of public agricultural research. The literature on agricultural research defines underfunding as a level of support lower than that which maximizes economic efficiency. The model shows that the main beneficiaries of successful research are consumers. The estimation of the weights for the PPF specification (2) indicates that the government places a relatively low value on consumer benefits, lower than is consistent with efficiency maximization. Hence the government will provide a level of consumer benefits lower than is economically efficient, which implies that the level of research funding will be lower than the efficient level. But this is exactly the underfunding that the literature on agricultural research seeks to explain. That is, the results presented here show that if the government places a relatively low value on consumers' surplus, and if the effects of research on the target price program and on government stocks are taken into account, then the policy-optimal level of public research support will remain below the economically efficient level of support.

Conclusions

The major contribution of this paper is the estimation of a policy preference function that explains the observed levels of public research funding, target prices, and sales from government stocks for the U.S. wheat sector. The estimated PPF places an 80% premium on wheat producers' surplus relative to wheat consumers' surplus, and the results indicate that the government values consumers' surplus at approximately 50% of the value of budget savings. With these relative values, the current levels of target prices and public research expenditures maximize the government's policy objective function. The government provides positive levels of research funds mainly because they increase consumers' surplus (benefit to producers are quite small). The funds are limited relative to economically efficient levels because successful research increases the cost of the target price program, and because the increase in consumers' surplus is valued less than budget savings.

Future work in PPF modeling could be directed toward including longer time periods and more commodities in the model. This will allow for more accurate description of policies and policy effects. It will cause the number of first-order conditions to exceed the number of policy instrument choices, bringing the estimation of PPF functions within the traditional econometric framework for analysis of overdetermined systems. The econometrician can then perform standard tests of hypotheses about political behavior.

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Political Preference Functions and Public Policy Reform

Gordon C. Rausser and William E. Foster

A model of policy making is developed where governments seek to maximize support from social groups through the combination of both PERT (social-welfare-increasing) and PERT (welfare-transferring) policies. The implicit weights of a political preference function shift with a change in the relative cost of interest group organizing. Attention is paid to the degree of wealth transfers as total social welfare increases because of PERT policy changes. The model demonstrates that, in the case of two competing groups, the weight given to one group in the allocation of social surplus will increase as total social welfare increases with a bias toward the other group. The relative weights placed on consumers and producers based on PEST policies alone are misleading indicators of the political influence of groups. A number of general implications of this political economic analysis for the reform of public policies are investigated.

Key words: agricultural policy, policy reform, preference functions, welfare.

Most analyses of policy reform, (e.g., Gardner, Stoeckel and Breckling), focus only on political economic-seeking transfer policies (PESTs). These policies are meant to redistribute wealth from one social group to another and are not directly concerned with efficiency. Other types of policies are PERTs, or political economic resource transaction policies (Rausser). These policies reduce transactions costs in the private sector by, for example, correcting market failures or providing public goods; they are ostensibly neutral with respect to their distributional effects. The distinction between the types of policies is briefly summarized by the popular metaphor of an economy as a pie: PERTs expand the size of the pie, and PESTs allocate the portions served.

The joint product approach to public policy involving both PESTs and PERTs avoids the extreme views found in the literature that focus either on government failures (rent seeking, directly unproductive profit-seeking activities, etc.) associated with the names of Buchanan and Tullock, Bhagwati, etc., or on market failures corrected by benign governments. We take the perspective in this paper that these extreme views only set the bounds on actual government behavior.

An analytical framework for jointly selecting PEST and PERT policies can be motivated by an example. Consider a public good that potentially can make both producers and consumers better off if there is some actual sharing of benefits. The market-exchange effects of this PERT in equilibrium, however, are such as to make producers worse off than without its dissemination. Specifically, total wealth increases (the economic pie expands) but, due to an inelastic demand, the distribution of benefits changes to the detriment of producers. Producers acting as a coalition may obstruct the implementation of the public good or PERT unless they are compensated in some form. One form of compensation is to introduce a PEST which transfers some wealth resulting from the new PERT equilibrium to producers. This transfer of wealth, the PEST, may actually be a means of securing the welfare-increasing policy even though it may appear as an inefficient rent-seeking based policy. As a result, the wealth transfer may be a crucial and Pareto-improving component of general policy. Under these circumstances, one major implication is that the social costs of PESTs should not be judged in isolation. The benefit of what may nominally be a PEST may lie in

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the PERTs which it allows to exist. Correspondingly, the benefits of a PERT may be less than those observed directly. To assure the PERT's political viability, some social costs may be incurred in the implementation of inefficient transfer schemes.

In the above setting, selected policies in a world of rational decision makers reflect an optimization game that can be modeled as a maximization of a reduced-form political preference function (*PPF*). Policies are in place, in part, because they serve the interest of those with relative political power and influence. The rational process generates a portfolio or mixture of PERT and PEST policies. There is a wide scope of possibilities to interchange the use of PESTs and PERTs so as to acquire, balance, and secure political power. The PERT/PEST integrated framework emphasizes transactions costs and provides the foundation for meaningful prescription. The framework has three major dimensions: the level of PEST intervention, the level of PERT intervention, and the choice of the policy instrument mix.

To illustrate the importance of the choice of the policy instrument mix, consider the U.S. proposal for agricultural reform tabled in Geneva on 25 October 1989. This proposal focuses on market access (tarrification and phase reductions), export competition (eliminates all export subsidies and export prohibition), internal support (phase out most trade-distorting policies, discipline less trade-distorting policies, and allow all minimally trade-distorting policies), and sanitary and phytosanitary provisions (promote harmonization and establish an international process for food safety, animal health and plant health trade disputes). All of these policies and their proposed adjustments represent different alternative policy instrument mixes. For example, the internal support component of the U.S. proposal involves changing the policy instrument mix by phasing out coupled PEST policies (e.g., administered price policies, income-support policies linked to production or marketing, transportation subsidies, etc.) and permitting or, in fact, substituting PERT policies (e.g., environmental and conservation programs, research extension, education, resource retirement programs, bona fide domestic food aid) and decoupled or neutral PEST policies (income support policies not linked to production or marketing). At any point in time, the selection of a particular configuration of instruments represents the choice of the policy mix.

This paper presents a new perspective on the political economy of policy reform. A straightforward model of policy making is developed where governments seek to maximize support from different social groups through the judicious combination of both PERT and PEST policies (Rausser). Particular attention is paid to the degree of wealth transfers (accomplished by the PEST) as total social welfare increases (accomplished by the PERT). The model demonstrates that, in the case of competing interest of two groups, the influence given to one group in the allocation of economic surpluses will increase as total social welfare increases with a bias toward the other group. PEST policies, while typically thought of as welfare transferring and efficiency decreasing, can be welfare increasing when combined with PERT policies which, by themselves, may be impossible to implement. The impossibility of implementation is due to their potentially detrimental effect on sufficiently powerful interest groups. The essential result is simply that the policies accomplishing the wealth transfers cannot be isolated from policies providing public goods. Practically speaking, what may appear to be socially wasteful and incoherent agricultural programs may actually be rationally designed schemes of compensation for larger, longer-term policies which expand total societal welfare.

Public Choice

Implications of recognizing that governments choose a mixture of PESTs and PERTs are drawn from a concrete model. This concrete model incorporates government behavior and the strategic behavior of various interest groups. To simplify the presentation, and without loss of generality, only two interest groups will be analyzed here—producers and consumers. The structural framework embraces the objectives and decision rules of the government as well as the two interest groups. Current policies represent equilibrium outcomes (perhaps short run) in political economic markets. In essence, observed policies can be treated as the result of the structural framework or, equivalently, as the outcome of maximizing the reduced-form political preference function (Rausser and de Gorter). This function does not necessarily represent the public interest or a social welfare function (Rausser and Freebairn). Arguments appearing in this preference function represent the performance measures (e.g., welfare surpluses, profits, etc.) that reflect the well being of each interest group.

The parameters of this preference function or the marginal effect of its arguments have been referred to in the literature as the preference weights (Rausser and Freebairn). If we fix the level of the PERT, these parameters (or equivalently, these weights) are "local." In the revealed preference and empirical analyses that have been conducted by economists, only such local weights have been estimated.

The formulated model presumes that the well being of each interest group can be accurately measured by consumer and producer surpluses (Gardner). In the political preference function, the implicit weights placed on consumer and producer surpluses in government decisions are shown to result from the degree to which those surpluses affect political support. The weights on a sum of consumer and producer surpluses reflect the degree of relative wealth transfers from one group to another, equal weights implying no transfers (Rausser and de Gorter). We demonstrate that these weights shift with a change in the cost of interest group organizing due to, say, an institutional change. More precisely, the relative weight on each group in the *PPF* is determined by an index of relative costs of political organization.

A decrease in a group's organizing costs relative to the other group's costs increases its responsiveness to changes in its collective welfare (i.e., the cost decrease leads to an increase in its marginal political power). Such a cost decrease would shift wealth transfers in its favor and, in this way, the weight changes on that group in *PPF*.[1] Policy reform, therefore, entails the alteration of the *PPF* through changes in the underlying costs to each group determining political support. Such changes in costs may ultimately be related to institutional reform or more simply to the subsidization of political activity.

The framework also demonstrates that judging the relative weights placed on consumers and producers based on PEST policies alone may be misleading. These weights are local in the sense that they reflect constrained government tradeoffs of group welfare for a given set of PERT policies. The implicit weights based on wealth transfers alone may favor one group, but the implicit weights based on the mixture of both PESTs and PERTs may indicate just the opposite.

[1] In our model, here, it is the marginal rate of political support with respect to a change in a group's welfare that is important in choice, not the absolute level.

Government Behavior

Consider a government in which politicians institute policies and programs in order to maximize the popular support from two groups, consumers and producers. The government realizes that its actions affect the two groups' economic welfare and that their welfare is directly related to their political support. A group's welfare is measured by its economic surplus—C or F, representing consumer and producer surplus measures, respectively. Given government actions, the levels of these surpluses are determined by the group's individual members acting in a decentralized way, consuming and producing in response to both market incentives and government policies. The government's policies have differential effects on the two groups, some combinations of programs benefiting both and some benefiting one while harming the other. The government, therefore, must make a decision on the configuration of policy that optimally trades off consumer and producer support through manipulation of their welfare.

The government's choice problem is simply reflected through the effects of its actions on a government support function, $S = S[S_c, S_f]$, where S_c represents support from consumers and S_f from producers. It is also hypothesized that informed organizations represent each group's interests. Their political activities on behalf of their collectives' welfare affect the responsiveness of the groups' supports to changes in the welfare measures. These organizations set the political environment, as it were, in which the government allocates society's total welfare between consumers and producers.

As noted above, PERT and PEST policies are available to the government in maximizing its support function through manipulation of consumer and producer welfare. The choice of both types of policies is constrained by the current state of technology, the state of managerial ability of politicians, and the state of theoretical and conceptual foundations on which to build policy. We assume that these realistic constraints on the set of feasible government actions lead to limits on the total available economic surplus possible and to a social cost of transfers between groups.

PERT policies are not neutral with respect to the benefits accruing to each group. Indeed, as noted above, PERTs may be sometimes consumer harming and sometimes producer harming. We reflect the choice of a PERT by the level of an index, E, such that as this index in-

creases the total surplus available increases. For any given PERT (i.e., for any given level of E), the general design of the PEST will be chosen to attain any particular level of surplus or, more generally, welfare transfer between groups with the least cost.[2] The government recognizes that, through its design of the PEST (e.g., the level of a price floor in combination with a level of import restrictions), it is setting both consumer and producer surplus levels.

There is in effect a surplus possibility frontier for every PERT policy that describes the highest possible level of the consumer group's economic welfare, C, for a given level of the producer group's welfare, F; i.e., $C = C(F|E)$. This surplus possibility frontier is represented in figure 1. The surplus frontier incorporates both the market structure of consumer and producer behavior as well as the available technology of welfare transfer.[3] Two conditions on this surplus transformation frontier are assumed to hold: over the relevant range, the welfare of one group decreases at an increasing rate with an increase in the welfare of the other (i.e., $\partial C/\partial F < 0$ and $\partial^2 C/\partial F^2 < 0$).

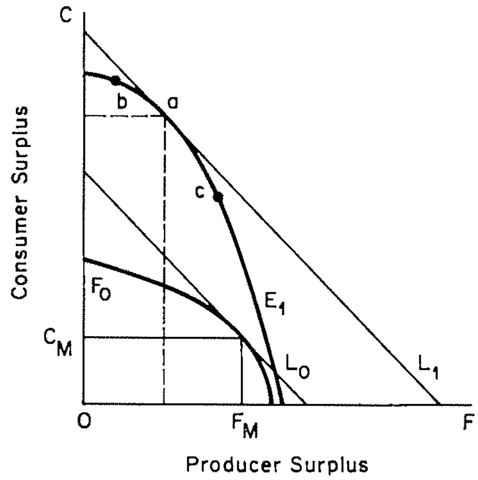

Figure 1. Surplus possibility frontiers under alternative PERTs

The surplus transformation frontiers for two levels of E are labeled E_0 and E_1, representing the movement from a lower level of total available surplus to a higher level due to the institution of a PERT and are graphically illustrated in figure 1. Without a PEST (without any transfers) the resulting equilibrium levels of consumer and producer surpluses occur at the point (C_M, F_M) where the surplus transformation curve has a negative slope of unity; that dollar from one group to another would be represented by the lines L_0 and L_1 passing through the free-market equilibrium combinations on E_0 and E_1. As the transformation frontiers are drawn, the implementation of the PERT causes the free-market combination of surpluses to move to point a in figure 1 where the free-market level of producer surplus has decreased. For example, such a producer-harming PERT would be the government's dissemination of a new supply-expanding technology that decentralized producers would adopt individually but which, in the presence of an inelastic demand, causes harm to the collective group.

Although the government's PERT and PEST decision is joint, the problem may be viewed in two stages. This is done for convenience purposes only; there is joint interaction and feedback between the stages regardless of how they might be structured. Because separability does not exist in the selection of the best mix of PERTs and PESTs, it makes little difference how the two stages are ordered. Here, the problem will be structured as one of determining the optimal

[2] We wish to emphasize that, in its most general form, our conceptual model can admit the possibility of government strategizing over the selection of the particular PEST instruments. We will set aside for the current discussion, however, the possibility that the government might purposefully introduce a degree of waste into surplus transfers for strategic ends. Such additional waste may result from the usefulness of a more wasteful transfer mechanism to (a) differentiate between decentralized decision makers and, thus, more cheaply counter political opposition by dividing and conquering and (b) encourage further rent-seeking activities of interest groups and, thus, perhaps to increase the government's political support. The first possibility is discussed and analyzed in Foster and Rausser.

Models of political competition between groups typically represent the government as a conduit of group pressure and the transfer scheme (the PEST) as a mechanism for rewarding or penalizing a group's relative political power. Heuristically, in such models the transfer mechanism implemented by the government would tend to be the most efficient. In the sense of minimizing deadweight losses, all groups can share in an efficiency gain. For example, Becker notes that competition among pressure groups favors efficient methods of taxation and sometimes (not necessarily always) efficient methods of subsidization (p. 386). Gardner uses this notion of efficient redistribution to explain why different forms of subsidization prevail over others under different market conditions. The methods of tax and subsidy in most models of political pressure serve the single purpose of allocating surpluses and, thus, these models suggest that the choice of PEST would not needlessly dissipate rents that could otherwise be enjoyed by at least one group. Closer to reality, however, the form of the PEST may also serve the other purposes of exploiting imperfect information or encouraging further rent seeking. The government may, in fact, weigh the relative inefficiency of a transfer scheme against, for example, its ability to hide its own inefficiency.

[3] Here, we are abstracting from the implementation costs of the transfer scheme and which group bears these costs. It is reasonable to assume that all groups share in these costs in the proportion that their memberships have in the total population. Thus, we assume that the group's shares of the implementation costs are not subject to strategic behavior and that they may be incorporated into the surplus transformation curve.

PESTs for each alternative level of a PERT. Once this has been determined, we then proceed to the best PERT policy conditioned upon the optimal (conditional) selection of the PEST. These two stages are offered as a simple way of interpreting the joint interactive algorithm that must be employed to determine the optimal instrument mix of PESTs and PERTs.

First, for a PERT (a level of E), the government chooses a constrained support-optimizing level of consumer and producer surpluses such that those levels lie on the surplus transformation curve. Its allocation of surpluses is dependent on the degree of rewards (increases in support) and penalties (decreases in support) offered by each group, and each group offers both greater rewards and penalties as it becomes more sensitive (or responsive) to changes in its collective welfare. At this stage, therefore, political organizations contend to enhance their clients' welfare by expending effort to make their respective groups more responsive and opposing groups less responsive to government action. This first stage corresponds to more narrowly focused models of near-term rent seeking where interest groups struggle over known resources in a known political economic environment.

The second stage corresponds to longer-term public decisions, to questions of infrastructure development and generally to policies not subject to the same organization strategizing as in the first stage. In this second stage, the government must make a discrete choice of a PERT policy, of altering the surplus possibility frontier. This choice of a PERT is not done in isolation: the choice of the best available PERT must also recognize the rent-seeking activities that occur whichever PERT is chosen. The government's decision to institute a PERT, therefore, is conditioned on the PEST (that is, an optimal rent-seeking surplus trade-off exists for every E) as well as the PEST conditioned on the PERT.[4]

The feasible means of surplus transfer dictates the concavity of the surplus transformation curve. The discovery of a more efficient method of transfer would lead to a shifting out of the transformation curve at every point except at the free-market, zero-transfer combination of group surpluses.[5] Taking as given the sensitivity of group support to welfare changes, the government wishes to choose the optimal combination of consumer and producer surpluses that falls along the available transformation curve. It will do so in the familiar marginalist way: The last dollar transferred will just balance the additional decrease in losers' support, with the additional gain in beneficiaries' support generated by that dollar, less the waste of the transfer.

$$\frac{\partial S_c}{\partial C}\cdot\frac{\partial C}{\partial F}+\frac{\partial S_f}{\partial F}=0. \tag{1}$$

Such a government choice would generally place the resulting combination of consumer and producer surpluses on one side or the other of the free-market point on the curve.

Political Preference Function

The relative weights on the two groups in the *PPF* will be a reflection of the government's allocation of surpluses which will, in turn, be the result of the political support offered by those groups. The *PPF* is a weighted average (here, arithmetic) of the group's surplus measures,

$$PPF = w\cdot C + (1-w)\cdot F,$$

implying that in equilibrium the weights on the two groups that would be consistent with the maximization of the *PPF* are such that

$$-\frac{\partial C}{\partial F}=\frac{(1-w)}{w}. \tag{2}$$

The surplus transformation frontier is a function of the particular PERT and the political support given by the two groups which is, in turn, a function of the costs of organizing activities, e_c and e_f, which we discuss below. Therefore, we may generally write $w = w(E, e_c, e_f)$. This weight is a local representation, dependent on the level of E.

Once the PEST policy has been decided, given each PERT choice, the government then chooses

[4] As in the case of implementing the PEST, we assume that the cost of implementing the PERT is borne by each group in some fixed proportion and not subject to strategic behavior. Thus, we assume that these costs may be incorporated into the degree of the outward shift of the surplus transformation frontier.

[5] Such a change in the transformation frontier would itself be a PERT and more generally should be subject to acceptance or rejection in the government's optimal selection of policies. Allowing that a more generalized view of the strategic government behavior is possible (following the remarks in footnote 3), we shall nevertheless confine ourselves to a choice among PERTs that leads to expansion of the transformation frontier at every point, that is, PERTs tht we refer to as pie expanding. We assume that any more efficient means of deviating from the free-market equilibrium of group surpluses is immediately adopted (as in Becker and Gardner).

the optimal PERT in seeking to maximize support. There is no straightforward rule of thumb for comparing among PERTs their constrained political equilibrium surplus combinations. The government's optimal PERT/PEST mix might lead to an increase in income transfers. For example, suppose that the best PEST policy has been decided for the case of E_0 in figure 1 and the constrained optimal level of transfers to either group is minimal—that is, the political economic equilibrium is (C_M, F_M). If the government chooses the level E_1, the resulting combination of group surpluses may be at point *c* where one group may be harmed, although that group may now receive significant transfers through the PEST. Indeed, more generally, it is possible that the deadweight loss per dollar transferred increases when moving from E_0 to E_1. Therefore, the narrow focus on only the PEST transfers in order to judge the relative power of interest groups may be misleading.

Strategic Behavior of Consumer and Producer Organizations

We assume that the support given to the government by each group is a function of its welfare as measured by its economic surplus and the effort expended by political organizations serving their clients' collective interests. These political organizations are considered endowed with the ability and information necessary to evaluate their clients' best interests in terms of seeking to maximize economic surplus.[6] Thus, these organizations attempt to make their clients' support functions as sensitive as economically justifiable to changes in surplus and to make the opposing group's support function as insensitive. Because of the limited information to decentralized decision makers, changes in welfare may not be connected in their minds with political decisions that otherwise might be influenced by threats or encouragement. Indeed, the problem facing the decentralized decision maker may be the inability to distinguish welfare changes caused by his government and changes caused by persons or events unconcerned with his or her political constituency. It is the purpose of the political organizations serving the decision maker to provide such information and to provide confusion or misinformation to the decision makers not so served.

In particular, consider the case of a producer organization expending effort, e_f, to increase the additional political support producers offer for an increase in the group's welfare. That is, the effort is meant to make producer support more responsive to an increase in F and, thus, to encourage the government to increase F at the expense of C for a given PERT. Similarly, the effort also mitigates any decrease in consumer support due to the change in surplus allocation. In marginalist terms, the producers' organization attempts to increase the marginal rate of producer support with respect to F, $\partial S_f/\partial F$, and reduce the marginal rate of consumer support with respect to C, $\partial S_c/\partial C$.

The consumers' organization expends a similar effort to increase the marginal rate of consumer support and reduce the rate of producer support. We take each group's marginal support as a function of the group's collective welfare and a measure of the relative effectiveness of the efforts expended by the political organizations. Let $n_c = n_c(e_c)$ and $n_f = n_f(e_f)$ measure the effectiveness or influence actually obtained by the organizations' efforts; in effect, effort is an input into the production of influence. Measure the relative influence of the groups by $\rho = n_c/n_f$. The marginal rates of support may be written as

$$(3) \qquad \frac{\partial S_c}{\partial C} = M_c(C, \rho), \text{ and } \frac{\partial S_f}{\partial F} = M_f(F, \rho),$$

where $\partial M_c/\partial \rho > 0$ and $\partial M_f/\partial \rho < 0$. Differential rates of organizational influence for the same level of effort may occur for several reasons. Political organizations may have varying degrees of expertise, professionalism, credibility, access to mass communications, and internal cohesion. Indeed, an "organization" as we have defined it may not be monolithic but a collection of smaller organizations drawn together by belief in a common cause but uncoordinated in their tactics.[7]

[6] A political organization may not strictly be the agent of a group's collective interest but rather have coincidental interests. The knowledgeable, but politically weak, organization may attempt to make its decentralized, but politically powerful, partner more responsive to government actions through the collection, analysis, and dissemination of information. Thus, in this way a political symbiosis is obtained which can be modeled as an organization and its client group.

[7] Although the use of a ratio of organizational efforts can be generalized by separately including e_c and e_f in the above functions, this complication yields little intuitive value for our present purposes. Nevertheless, it is important to note that advertising and promotion messages from the consumer's organization would be just as effective as if the same information was advanced by the producer organization. In this sense the organizations can hide their identities or true purpose. Also implicit is that organizations' activities are not aimed at specific groups. That is, the effort of an organization is not tailored to influencing only the marginal support of a single group.

The unit cost of effort to the consumers' organization is represented by k_c and to the producers' organization by k_f. Differential costs of political activity may arise from several sources, the most important of which is the transactions costs of developing and maintaining politically cohesive groups. For smaller, more homogenous groups, such as farmers in the developed world, the costs of organizing, identifying, informing, and coordinating group membership is relatively low. For larger, diverse groups, such as consumers in the developed world, costs of similar organizational activities are relatively large.

The Level of Wealth Transfer and the PPF Weight Determination

In order for these political organizations to have a role in this model, they must anticipate the effects of their activities on the welfare of their client groups. That is, the organizations understand how their efforts alter government incentives to allocate welfare across groups. In this sense, each organization behaves as a Stackelberg leader with respect to the government's choice of optimal wealth transfer. Intuitively, the organizations are setting the political terrain over which the government seeks to gather the greatest support. With respect to wealth transfers, the two organizations are gaming over the structure of support trade-offs—the iso-support curves of the government-choice problem—leaving the government to find the optimal "consumption" of consumer and producer surpluses along the surplus possibilities frontier, $C = C(F)$.

Each organization wishes to maximize its client group's economic surplus net of the cost of the effort expended. With knowledge of how changes in marginal rates of support affect government support and taking the activity of the opposing organization as given, each organization will expend effort until the marginal gain in its group's surplus is just equal to the unit cost of effort. From the government's decision rule given by expression (1), the definition of the marginal rates of support given by expression (3), and the surplus transformation frontier $C = C(F)$, we can find each organization's reaction function in terms of the PERT, E, and the political effort of the other organization,

$$\text{(4)}\quad \frac{\partial F}{\partial e_f} = \frac{1}{\Delta}\frac{\rho}{e_f}\xi_f\left(\frac{\partial M_c}{\partial \rho}\frac{\partial C}{\partial F} + \frac{\partial M_f}{\partial \rho}\right) = k_f,$$

$$\text{(5)}\quad \frac{\partial C}{\partial F}\frac{\partial F}{\partial e_c} = \frac{\partial C}{\partial F}\frac{-1}{\Delta}\frac{\rho}{e_c}\xi_c\left(\frac{\partial M_c}{\partial \rho}\frac{\partial C}{\partial F} + \frac{\partial M_f}{\partial \rho}\right) = k_c,$$

where ξ_f and ξ_i are the elasticities of effective influence with respect to effort [i.e., $\xi_i = (e_i/n_i)(\partial n_i/\partial e_i)$]. In equilibrium, the optimal level of effort of each organization must be consistent with the effort of its opponent and the government's actions consistent with that political activity.

From the above expressions and the discussion of the implied *PPF*, expression (2), we draw our first result regarding the local *PPF* weights,

$$\text{(6)}\quad \frac{1-w}{w} = -\frac{\partial C}{\partial F} = \frac{e_c k_c}{e_f k_f}\frac{\xi_f}{\xi_c}.$$

That is, the relative weight placed on producers in equilibrium is proportional to the ratio of marginal costs of political activity. For given relative effective efforts in equilibrium (i.e., a fixed equilibrium, ρ), a greater marginal cost of effort by the consumers' organization, *ceteris paribus*, leads to a reduction in the *PPF* weight on consumer welfare.

The levels of effort expended by the two groups, however, will change with changes in the relative marginal costs of organizational activity. We may determine the equilibrium effects of an increase in relative costs by noting that expressions (1) and (6) must hold in equilibrium for every PERT and every ratio of costs, determining both the equilibrium levels of producer surplus [taking $C = C(F|E)$] and the ratio of political organizing efforts. Define the parameters $\eta = e_c/e_f$ and $\theta = k_c/k_f$ and let $\xi_c\ \xi_f$. From expression (1),

$$\text{(7a)}\quad \left(\frac{dF}{de_c}\right) = -\left(\frac{1}{\Delta}\right)\frac{\rho}{e_c}\xi_c\left(\frac{\partial M_f}{\partial \rho} + \frac{\partial M_c}{\partial \rho}\cdot\frac{\partial C}{\partial F}\right) < 0,$$

$$\text{(7b)}\quad \left(\frac{dF}{de_f}\right) = \left(\frac{1}{\Delta}\right)\frac{\rho}{e_f}\xi_f\left(\frac{\partial M_f}{\partial \rho} + \frac{\partial M_c}{\partial \rho}\cdot\frac{\partial C}{\partial F}\right) > 0,$$

where $\Delta = \partial^2 S/\partial F^2 < 0$. From expression (6), (7a), and (7b), we may sign

$$\text{(8a)}\quad \frac{de_c}{d\theta}\frac{1}{e_c} - \frac{de_f}{d\theta}\frac{1}{e_f} = \frac{-\eta}{C_{ff}\dfrac{dF}{de_c}e_c - \dfrac{(1-w)}{w}} < 0,$$

(8b)
$$\frac{dF}{d\theta} = e_c \frac{dF}{de_c}\left(\frac{de_c}{d\theta}\frac{1}{e_c} - \frac{de_f}{d\theta}\frac{1}{e_f}\right) > 0,$$

where $C_{ff} = \partial^2 C/\partial F^2 < 0$. Finally, note that

(9)
$$\frac{d(1-\omega)/\omega}{dF} < 0.$$

Hence, we may state the following intuitively appealing result:

> Defining the (local) weights on group welfare in the *PPF* as those consistent with government wealth transfer policy for a given PERT, an increase in an organization's marginal cost of political activity, relative to the opposing organization's cost, will decrease the weight on its client group's welfare.

In particular, a decrease in the relative cost of political activity of the consumers' organization will increase the effort that organization expends and will decrease the effort that the producers' organization expends. This, in turn, will lead to an increase in the consumer group's welfare (and a decrease in F). As C increases and F decreases, the degree of wealth transfer moves in favor of consumers and, thus, the weight on the consumers in the PPF increases.

The Introduction of a Pie-Expanding PERT

Consider the government's decision to introduce a PERT policy which expands the surplus transformation frontier at every point. That is, the government may move from the selection of E_0 to E_1, implying that, for every F, $C(F|E_1) > C(F|E_0)$. Furthermore, consider the case of a consumer-biased change in PERT policies. We define such a biased shift such that the difference, $C(F|E_1) - C(F|E_0)$, grows as F decreases. In terms of incremental expansions of the surplus transformation curve, a consumer-biased shift implies $\partial^2 C/\partial F \partial E < 0$.

Intuitively, a consumer-biased shift would result in a free-market equilibrium where consumers are better off but producers are worse off. Furthermore, in terms of wealth transfer policies, a given increase in producer welfare through a PEST will come at a greater decrease in consumer welfare under E_1 than under E_0; thus, the marginal loss in consumer support for the marginal transfer from any level of C would be greater. In effect, the producers' organization would find it more difficult to induce the government to transfer additional income from consumers from given levels of surplus allocation and political activity.

Suppose that, in this second stage of public policy making, the government accepts the PERT; that is, let $S[S_c(C_1, \rho_1), S_f(F_1, \rho_1)] > S[S_c(C_0, \rho_0), S_f(F_0, \rho_0)]$. We are interested in the resulting degree of wealth transfers that take place under these new political economic conditions. In terms of the *PPF*, how do the constrained weights on group surplus change with the move to E_1? The answer is that the local weight on producer surplus increases although producer surplus may decrease with the move from E_0 to E_1.

We now prove this result. Note that the *PPF* weights are indicated by the value of η—the relative organizational efforts—in equilibrium as indicated in expression (6). Define $\eta_0 = e_{c0}/e_{f0}$ and $\eta_1 = e_{c1}/e_{f1}$; where $\rho_0 = n_c(e_{c0})/n_f(e_{f0})$ and $\rho_1 = n_c(e_{c1})/n_f(e_{f1})$. It is assumed that $\rho_0 \gtreqless \rho_i$ as $\eta_0 \gtreqless \eta_1$. The weight on producers increases if $\eta_1 > \eta_0$ or if $\rho_1 > \rho_0$; that is, if the equilibrium allocation of surpluses is such that the slope of the surplus transformation curve is greater under the new PERT, $-\partial C(F|E_1)/\partial F > -\partial C(F|E_0)/\partial F$. For example, in figure 1 an initial equilibrium of (C_M, F_M) would imply $\eta_0 = 1$. The weight on producers would increase ($\eta_1 > 1$) with a new equilibrium at point c. To show this, suppose the opposite case, that $\eta_1 \leq \eta_0$ or $\rho_1 \leq \rho_0$, which implies that, since the move from E_0 to E_1 is consumer biased, producer surplus must fall and consumer surplus must rise, $F_1 < F_0$, $C_1 > C_0$. In other words, if $\rho_1 \leq \rho_0$, then the new equilibrium under E_1 would be represented by a point such as b in figure 1. Concavity of the marginal support functions assure that, if $\rho_1 < \rho_0$,

(10)
$$M_c(C_1, \rho_1) < M_c(C_0, \rho_0) \text{ and}$$
$$M_f(F_1, \rho_1) > M_f(F_0, \rho_0);$$

thus, $M_{f1}/M_{c1} > M_{f0}/M_{c0}$. From the government's optimal allocation of surpluses under each PERT, however, $\eta_i\theta(\xi_f/\xi_c) = M_{fi}/M_{ci}$, and we have a contradiction. Hence, we may state the following result:

> Government choice of a consumer-biased PERT leads to an increase in the (local) weight on producers in the *PPF*.

Intuitively, the conditions expressed by (10) imply that consumer sensitivity to surplus changes falls the greater that group's welfare and the lower the relative level of pro-consumer political activity. Similarly, producer sensitivity rises the lower that group's welfare and the higher the relative level of pro-producer activity. In equi-

librium, one would not observe both a decline in producer welfare, an increase in pro-producer effort, and at the same time a decrease in that group's sensitivity to changes in its welfare. The result simply says that, in general, governments will place less weight on any interest group that grows more satisfied and expends less lobbying effort.

This is not to say that both consumer and producer welfare grow but that the degree of wealth transfer (from the noninterventionist point) grows in the producers' favor. In fact, the equilibrium surplus to producers may fall with an introduction in the PERT at the same time the constrained weights on producers may increase in the *PPF*.[8]

Local and Global PPF Weights

The weights on consumers and producers in the conventional *PPF* are local in the sense that they reflect only trade-offs between group welfare measures in the choice of the level of wealth transfer for a given PERT. In a similar manner one may think of the government choosing a PERT conditional on a particular transfer mechanism and level of wealth transfer, that is, given a PEST. In this latter case, also, one would observe weights on each group that reflected only trade-offs in the choice of the PERT. The choice of the PERT is the selection of the surplus possibility frontier $C(F|E)$ along which the government ultimately selects the optimal combination of surpluses. If one does not take into account that the PEST instruments and/or levels may change from one PERT to another, then one may draw erroneous conclusions regarding the relative group weightings.

Figure 2 illustrates the hazards of assessing

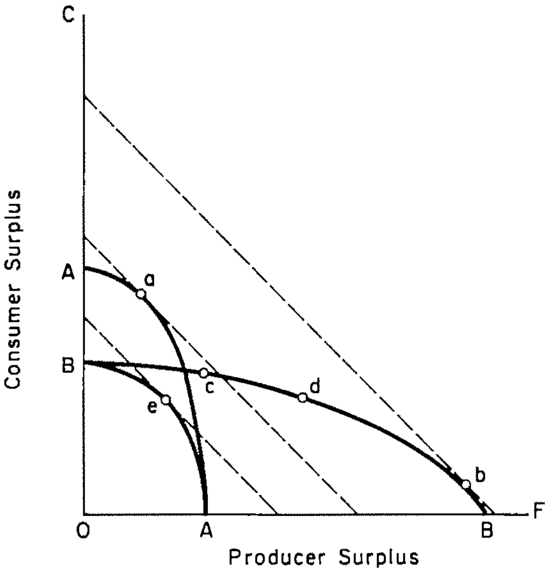

Figure 2. Alternative surplus possibility frontiers for choice of PERT

trade-offs between welfare levels by focusing only on a PERT policy decision. Suppose the government has the choice of moving from a base surplus possibility frontier given by curve *BA* to either of two frontiers given by curves *AA* and *BB*. These two PERTs correspond to a consumer-biased pie-expanding policy and to one that is producer biased. The government chooses curve *AA* and the surplus combination given by point *a*. The point *a* is selected by the particular level of wealth transfer accomplished by the PEST. In this case, for convenience, the level of transfer is zero and a free-market outcome is the result which, in this illustration, is represented by the straight line tangent to curve *AA* at point *a*. Now, if one were to compare total welfare possibilities under the PERT yielding curve *AA* with that yielding curve *BB*, given the existing transfer scheme and level, one would conclude that the weight on consumer relative to producer surplus must be high. The total surplus given the existing PEST for curve *BB* is greater than that for curve *AA*, implying that the government must be willing to forego more than a unit of producer surplus for a unit of consumer surplus. In reality, however, the level of wealth transferred by the PEST under the PERT yielding curve *AA* would not be the same level as under the PERT yielding curve *BB*. Indeed, the optimal surplus combination conditional on being on curve *BB* will be to the left of point *b*, implying less weight on consumers relative to producers. The optimal combination under the pro-

[8] A sufficient condition for an incremental increase in E to lead to a decline in producer surplus is found from the expressions defining the political economic equilibrium (1) and (6). After some comparative statics manipulations,

$$dF/dE = -(AC_{f\epsilon} - \theta B)/(C_{ff}A - \theta\Delta),$$

where $A < 0$ is the derivative of expression (1) with respect to ρ, B is the derivative of (1) with respect to E, and $\Delta < 0$ is the second-order condition of the government's optimization problem. Now, the denominator of the above expression is positive, so a sufficient condition for the entire expression to be of negative sign as if $B < 0$; that is, if

$$B = \partial M_c/\partial C . \partial C/\partial E . \partial C/\partial F + C_{f\epsilon} . M_c .$$

Intuitively, producer welfare will decrease in equilibrium if the percentage decline in consumer sensitivity to a welfare change is less than the increase in the slope of the surplus possibility frontier (i.e., the slope becomes more negative).

ducer-biased PERT may be, in fact, at a point such as point *c*, implying that the surplus combination is consistent with more equal weighting between groups if not a relatively greater weight for producers.

Local weights reflected by a PERT selection would change as constraints on PESTs change, just as in the previous section where the local weights changed with the introduction of a PERT. Pie-expanding PERTs are usually associated with infrastructure development, technological R&D, and other policies usually thought to promote economic progress. The choice set of PESTs, on the other hand, is usually considered a given. Nevertheless, constraints on the choice of transfer schemes do exist and change over time. External events, such as changes in the cost of financing, may alter the potential choices of PESTs and, thus, also alter the final equilibrium choice of both PEST and PERT. Other countries and international agencies may impose restrictions on the wealth transfer policies of some governments for their own purposes. Finally, technological developments, and other advances usually disassociated from rent-seeking and wealth transfers, will alter the shape of the surplus possibilities frontier itself. For example, better mechanisms for tax collection may imply less distortion relative to taxation via the manipulation of commodity prices.

Take, for example, the case of an outside agency, such as the World Bank, imposing certain constraints on a government's choice of wealth transfer policies. The agency considers its own objectives consistent with an expansion of total social welfare, as measured by the equal-weighted sum of consumer and producer surpluses, in the country in question. Using only observed local weights on the choice of the PEST, for a given PERT, the agency may conclude that all that is needed to expand welfare is to balance the weights on groups represented in the *PPF*. It seeks to effect this equal-weighting outcome by constraining the government to using the market to allocate social welfare. By constraining the PEST, however, the only instrument left to the government to maximize its support is its choice of PERT. The result may very well be a decrease in total social welfare as the government alters the surplus possibility frontier.

This possibility is illustrated in figure 2. Suppose the point *e* represents an initial political economic equilibrium on the surplus possibilities frontier given by curve *BA*. Point *e* happens to be a noninterventionist outcome. A future political economic equilibrium, conditional on two potential PERTs discussed above, is given by the surplus combination at point *d*. The free-market equilibria under the two PERTs are given by points *a* and *b*. The combination of group surpluses given by point *d* lies to the northeast of point *e* and is consistent with the outcome of a cooperative game with the conflict point *e* being the outcome if either consumers or producers veto a move from the original situation.

Suppose some outside agency, anticipating the apparent relative strength of consumers and hoping to maximize future total social welfare, enters the game between consumer and producer organizations and the government and constrains the government to enforcing free-market allocations. Suppose the outcome represented by point *b* is unacceptable to consumers and the government finds, of the two free-market points, that the outcome given by point *a* maximizes its support. Although the surplus combination given by point *a* is a free-market one, it yields nevertheless a smaller total sum of equally weighted consumer and producer welfare measures than that associated with point *d*.

In fact, as illustrated, there is a loss in the welfare of producers relative to the initial equilibrium point on curve *BA* and, thus, point *a* is inconsistent with a cooperative game. If producers and consumers have a veto over any move from the initial equilibrium that causes a decrease in their welfare and the only choices are constrained to be at points *a* and *b*, then the outcome will be no PERT at all. The outcome of an outside agency's constraint on the operation of a PEST would be a surplus combination given by point *e*, implying not only a decrease in the total sum of surpluses but a decrease in the welfare of both groups.

Implications and Concluding Remarks

The primary implication of the model is that the introduction of an expansion of total social welfare biased toward one group (e.g., a consumer-biased PERT) leads to a change in the degree of wealth transfer in favor of the other group. That is, a biased PERT such as a technical advance with inelastic demand yields an increase in the local PPF weight on the group not favored by the PERT. Moreover, although the local weight on a group may increase with the introduction of a pie-expanding PERT, the group's actual welfare may decline. The degree of wealth transfer relative to a noninterventionist state will increase, but absolute welfare of the PEST ben-

eficiary will decline if the new noninterventionist allocation of surpluses does sufficient harm to that group.

The *PPF* is a reduced-form expression of the more complicated (and richer) structure of a political system. Therefore, when speaking about reform (and almost always one is referring to ending wealth-seeking transfers), one is implicitly, if not explicitly, speaking about changing the weights on groups in the *PPF*. Grudging reforms, forced on a political system by an outside government or international body, will fail if these underlying weights remain unchanged. Such reforms will be temporary reactions to external demands and, once those demands abate, the political system will likely return to its previous policy equilibrium. Only if outside pressures force the restructuring of the weights of institutions would such reforms be permanent.

Indeed, unless the weights in the *PPF* change, unsustainable alterations in agricultural policies should not be termed reforms at all. To move from a current mixture of policies to sustainable reforms entails the movement from one policy equilibrium to another. The emphasis of this perspective is on a government's problem of selecting the mixture of public goods and transfers that maximizes its political support. Simply put, reforming food and farm policies implies changing the forces conditioning government behavior.

The movement from one equilibrium to another, with a new discrete selection of a PERT and PEST mixture, is equivalent to eliminating a missing market. As with the Coase theorem, if all parties negotiate efficiently, then the existence of incomplete political economic markets is not an obstacle to efficient policy reforms. However, because of transactions costs and incomplete information, the Coase theorem does not provide an attractive solution. In this instance we are left with no alternative but to turn to collective action or government behavior to effectively lower the transactions costs and provide more adequate information so that a market for reform naturally emerges. For this argument to make sense, we must appeal to the economies of size, the willingness of governments to impose effective penalties and rewards, and new negotiation techniques.

The demand for reform is an increasing function of the degree of social waste generated by wealth transfer programs but the supply of reform is not. Much like the demand for goods imagined, but yet beyond the present state of technology to produce profitably, the demand for reform will remain unfulfilled without a change in a country's political technology. The reform of agricultural policies must come through changes in the means of compensating groups who would otherwise be losers or through institutional changes in the relative costs of political activity by groups paying the compensation (typically consumers). If we do not see a supply of reform, then we must not despair for the economic rationality of governments. We must, instead, invent the intellectual and political machinery that will allow reform to be profitably supplied.

From the perspective developed here, reforms that lessen the distortionary and inefficient aspects of agricultural policy may be induced from two important sources—the development of less wasteful means of compensation and the lowering of costs associated with making those paying the compensation more sensitive to government decisions. Developing better compensation schemes may be thought of as finding improved means to negotiate the allocation of society's welfare. Valuable transactions can take place between consumers and producers, involving the savings of many wasted resources, and yet these transactions remain unnegotiated. This is, in part, because there are no satisfactory means of satisfying both groups because of the inadequate stock of ideas. Rather than altering the political power relationships between groups, reform may be accomplished by demonstrating the feasibility of alternative, more efficient programs of wealth transfer. In the framework of the analytical model, the introduction of a less wasteful transfer scheme would be an expansion of the surplus possibility frontier at every combination of consumer and producer surplus levels (except at the free market point). Such an alteration in the surplus transformation curve would imply that the PEST more closely approximates a lump-sum transfer. In a world of perfect knowledge, where every imaginable type of policy is possible, nondistorting lump-sum transfers would be the government's optimal means of allocating society's welfare. In the real world, however, a lump-sum transfer most often is not a practical means but rather a standard by which we can measure how advanced is the state of the art in wealth transfers.

A second means of obtaining sustained reforms is a change in the relative costs of organizing those who would benefit by those reforms. By increasing the responsiveness of a group—in particular, consumers and taxpayers in the developed world—to changes in its wel-

fare, the government would take advantage of present transfer mechanisms and would move the allocation of surpluses to less wasteful combinations. Reducing the costs of organizing the beneficiaries of reform may be done in several ways—from direct subsidization to the reform of the institutions in which political activity takes place. The direct subsidization of efforts to increase the sensitivity of consumer/taxpayer groups in the developed world may, at first glance, seem to hold little promise. Nevertheless, some countries do have institutional arrangements to keep watch over consumer interests, and the experience of Australia, for example, could serve as a model for other nations. One should note, however, that the expense of decreasing the cost of pro-consumer activity and increasing the cost of pro-producer activity must be borne, at least in part if not in full, by those potential winners outside a political system targeted for reform.

The point is to move to a new political equilibrium, and this implies changing the structure on which outcomes hang; after all, for the case of constant political technology, if changing the relative costs of political activity were a simple matter of decisions made within the political system, then presumably it would already have been done. External groups (even entire nations), who would gain coincidentally with the strengthened political power of internal groups, must therefore carry part of the responsibility of beginning the reform process; and they must be prepared to share in the direct expense of increasing pro-reform activities.

There are, in addition, less direct ways of lowering the cost of organizing pro-consumer activities such as the provision of information regarding the welfare effects of government policies. Such transparency analysis has developed a great many proponents in the last several years. Although greater information to potential beneficiaries of reform may be necessary to motivate opposition to the present state of wealth transfer schemes, there are significant reasons to believe that improved knowledge will not be sufficient. First, to place all the emphasis on making transparent the effects of a government's agricultural policies implies a severe lack of intelligence by those who bear the cost of wealth transfers. Yet, food and farm policies have been in place for decades, consumers especially have enjoyed ever-cheapening food prices, and the developed world goes on in apparent good order despite the years of social waste. Second, improved knowledge is subject to the same politicization and manipulation as other information and misinformation supplied to interest groups.

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Adoption Ceilings and Modern Coarse Cereal Cultivars in India

Hans G. P. Jansen, Thomas S. Walker, and Randolph Barker

The concept of, and evidence for, regional adoption ceilings is assessed for modern coarse cereal cultivars in India. Adoption is defined as the proportion of total area of a given coarse cereal planted to modern cultivars. Agroclimatic and soil differences are more important than disparities in infrastructure in explaining the variation across regions in estimated adoption ceilings. Qualitatively different modern cultivars from those now released are necessary to change regional adoption behavior. The results support an agricultural research strategy that gives higher priority to more regionally oriented breeding and testing programs in preference to the past emphasis on wide adaptation.

Key words: adoption ceilings, coarse cereals, modern cultivars.

Modern cereal cultivars were released throughout India in the 1960s.[1] Across the major cereals of wheat, rice, sorghum, pearl millet, and maize, the modern cultivars (MCs) represented a substantial change from local varietal types. MCs were photoperiod-insensitive, fertilizer-responsive, and short statured. Grown with good management on fertile soil with access to reliable rainfall, they gave markedly heavier grain yields than local varieties.

By the mid-1980s, the pattern of diffusion of MCs varied sharply among cereals and across space. The wheat MCs had largely completed their diffusion process (Dalrymple 1986b). Rice MCs had also been adopted on most of the area planted to paddy (Dalrymple 1986a). Coarse cereal MCs had penetrated into many major producing regions, but their uptake by farmers has been less uniform than for wheat and rice MCs (table 1).

In India, coarse cereals are mainly produced in the harsh production environment of rainfed agriculture which is often beset by considerable location specificity in the incidence of physical and biotic stress. Rural infrastructure in the major coarse cereal-growing regions is also often poor relative to the better endowed, more heavily irrigated areas (Wanmali).

A notable characteristic about the adoption performance of coarse cereal MCs in India is the persistence of "ceiling" levels of adoption during the 1980s. For many producing regions, adoption has oscillated around a plateau significantly less than 100%. This research seeks to (*a*) assess the relative importance of climatic, edaphic, and infrastructural factors in constraining regional adoption, and (*b*) to draw implications for agricultural investment and research strategy to increase the hypothesized ceiling levels of MC adoption.

The research represents a departure from the previous literature (Griliches 1957, Martinez, Wattleworth) in two important ways. First, the emphasis is not on explaining interregional variation in the speed of diffusion but on understanding spatial differences in endogenously estimated ceiling rates of adoption (Griliches 1980). This emphasis addresses enduring regional imbalances in MC adoption and reflects the view that welfare levels are usually determined by who ultimately adopts rather than by who first adopts (Gerhart). Second, the focus is on whether aggregate diffusion analysis of secondary data can generate insight on the desirability of investing research resources in specific-trait improvement.

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[1] The word cultivar includes both open-pollinated varieties and hybrids.

Table 1. Progress of Area Under Modern Cultivars in India, 1966–67 to 1984–85

	Year						
Crop	66–67	71–72	75–76	80–81	82–83	83–84	84–85
Rice[a]	0.88	7.41	12.44	18.23	18.84	21.74	23.44
	(2.5)	(19.6)	(32.8)	(45.4)	(49.9)	(53.0)	(60.4)
Wheat	0.54	7.86	13.46	16.10	17.84	19.39	19.58
	(4.1)	(41.1)	(74.7)	(72.3)	(77.1)	(79.5)	(83.1)
Sorghum	0.19	0.69	1.96	3.50	4.37	5.28	5.09
	(1.1)	(4.1)	(12.1)	(22.1)	(27.1)	(32.5)	(32.5)
Pearl	0.06	1.77	2.90	3.64	4.71	5.42	5.25
millet	(0.5)	(15.0)	(25.7)	(31.2)	(43.1)	(45.9)	(49.1)
Maize	0.21	0.44	1.13	1.60	1.72	1.91	2.06
	(4.2)	(7.6)	(19.3)	(26.7)	(30.1)	(32.4)	(36.2)

Source: Government of India: various issues of *Indian Agriculture in Brief*, *Agricultural Situation in India*, and *Economic Survey*; Dalrymple (1986a,b).
[a] First row for each crop is million hectares; second row is percentage of total crop area.

Adoption Ceilings: Concept and Context

The diffusion path of aggregate adoption of a new technology often resembles a sigmoid curve, largely reflecting the dynamics of the spread of information (Feder, Just, and Zilberman). The long-run upper limit or ceiling on aggregate adoption is determined by the economic characteristics of the new technology and by the state of the economy (Griliches 1980).

Although long-run upper limits are associated with permanency, these levels can shift upwards over time in response to "second generation" technical change. For example, in 1957 Griliches estimated aggregate diffusion ceilings on corn hybrids of less than 100% for many states and crop reporting districts in the United States. Shortly thereafter, hybrids had entirely replaced open-pollinated varieties in the same regions (Dixon).

The need for and the impact of second generation technical change in shifting up initial adoption ceilings is illustrated in figure 1 for two cereal-producing regions. The first is the idealized case; the second is what often happens. In homogenous region A, the first-released groups of MCs are economically and uniformly superior to the local varieties; consequently, the long-run level of adoption of 100% is quickly attained. In contrast in heterogenous region B, the first-generation MCs are more profitable than local varieties in only some selected locales, probably those of higher production potential. As a result, the adoption ceiling falls far short of 100%. Suppose at time t^* second-generation MCs are released to farmers. If the second-generation MCs are successful in addressing the location-specific problems of earlier MCs, full

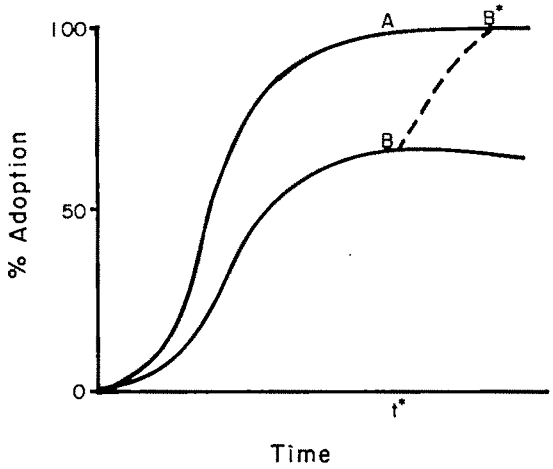

Figure 1. Adoption ceilings and second generation technical change in two regions

adoption may still occur but on a secondary diffusion path such as the dotted line in figure 1.

Although the concept of an adoption ceiling is potentially useful, it can be empirically elusive. Because agricultural technologies are ultimately location specific and because administrative reporting units are usually comprised of multiple soil and rainfall environments, ceiling levels of adoption can vary substantially. More important, data on area planted to specific cultivars are often not available. Usually, one has access only to the area planted to MCs as a whole. Therefore, one cannot distinguish between the adoption profiles of the first and second generation MCs in figure 1.

In other words, estimating an aggregate adoption curve on OBB^* may give results that are neither fish nor fowl. As Griliches (1980) points

out, the slow upper tail may be associated with the lack of well-adapted MCs, thereby confounding summary information on the speed of acceptance of the innovation. To overcome this problem, Griliches recommends that aggregate adoption analysts use a model with an endogenous and shifting ceiling parameter. Alternatively, one can choose a time horizon that largely restricts the analysis to the first wave of MCs, as occurs in this paper.

With the exception of some maize composites, the first wave of modern coarse cereal cultivars was largely synonymous with hybrids. Exotic lines and foreign breeding efforts played a crucial role in their development, and selection procedures in breeding were heavily biased towards yield potential and wide adaptability. Improved open-pollinated sorghum and pearl millet varieties were introduced commercially on a wider scale only in the early to mid-1980s.

By the mid-1980s in India, second and third generation modern coarse cereal cultivars had been introduced only recently or were not that qualitatively distinct from their first generation counterparts. Incentives in public-sector plant breeding still centered on national yield performance in multilocational trials. The emphasis on wide adoption did not explicitly address the more specific problems of ecological niches. Hence, except for the second generation pearl millet hybrids and to a lesser extent later maize hybrids and composites, the period ending in 1983–84 corresponds mainly to the diffusion of the first batch of MCs.

Later generation technical change is not the only plausible explanation for upward shifts in adoption ceilings in figure 1. Expanding and deepening rural infrastructure could also lead to increasing equilibrium adoption levels. But changes in rural infrastructure likely would have a greater effect on the earlier than on the later properties of the diffusion process. Improving rural infrastructure can result in higher profitability of the more input-intensive MCs, but it cannot fully compensate or directly substitute for susceptibility to physical and biotic stress that constrain profitability of MCs.

Estimation

The research method is a modified version of Griliches' (1957) two-stage approach that has been widely used to examine adoption behavior (e.g., Martinez, Globerman, Romeo, Rapoport, Wattleworth, Jarvis).

First Stage

The first stage consists of fitting a logistic curve to the historical diffusion data, thus summarizing, for each cross-sectional entity, the adoption process in two parameters: the diffusion speed and the adoption ceiling.[2] The first-stage logistic equation is

$$(1) \qquad F_i(t) = y_i/(1 + \exp(-a_i - b_i t)),$$

where $F_i(t)$ is the cumulative percentage of area sown with MCs for production region i and time t, y is the ceiling coefficient or long-run equilibrium value, b is the diffusion speed coefficient, and a is a constant of integration that positions the curve on the time scale. Treating the ceiling level of adoption as endogenous results in a nonlinear estimation problem which can be solved only through numerical optimization. Marquardt's method was used to generate the nonlinear logistic estimate of the ceiling coefficient y (Judge et al.).

Second Stage

The second stage examines the determinants of the variation in the first-stage estimates by hypothesizing that the adoption ceilings are functions of specific sets of variables. Because the estimated adoption ceilings lie between 0 and 1 (or between 0 and 100%), the dependent variable is truncated, and a linear probability model (LPM) estimated with ordinary least squares (OLS) is inappropriate (Judge et al.). A popular alternative to a LPM is the logistic specification (2).

$$(2) \qquad y_i = (1 + \exp(-a - bX_i - e_i))^{-1}.$$

Equation (2) is often transformed into the linear logit model (3) which can be estimated by OLS:

$$(3) \qquad \ln (y_i/(1 - y_i)) = a + bX_i + e_i.$$

Two methodological improvements on (2) or (3) are offered for the second-stage estimation. The first improvement derives from the notion that the slope of the cumulative logistic probability function is greatest at the midpoint. Therefore, changes in explanatory variables will have their greatest impact on the dependent

[2] Weibull and Gompertz functions were also fitted to the time-series adoption data to allow for asymmetry in aggregate adoption behavior (Dixon). Based on goodness-of-fit criteria, neither the Weibull nor the Gompertz was a significant improvement over the logistic (Jansen).

variable at the midpoint of the distribution. Similarly, the low slopes near the endpoints of the distribution imply that relatively large changes in the independent variables are necessary to bring about a small change in the dependent variable. Because the tail values of the dependent variables are associated with large errors, in a proportional sense, the logit model in (2) with its multiplicative error structure is not ideal. To redress this implicit weighting imbalance, the logit model in (4) with an additive error structure was used.

$$(4) \qquad y_i = (1 + \exp(-a - bX_i))^{-1} + e_i.$$

The second improvement is an application of generalized least squares. It was first applied in aggregate diffusion analysis by Wattleworth. The information embedded in the different standard errors of the adoption ceilings estimated in the first stage can be used to derive more accurate second-stage parameter estimates. Consequently, each error term e_i is assumed normally distributed with variance σ_i^2, where $\mathrm{Var}(e_i) = E(e_i^2) = \sigma_i^2$ is not constant across production regions. Each observation on all variables in the second stage was divided by the standard error of the estimated adoption ceiling, and weighted least squares was used to estimate (4).

In addition, each observation in the second stage was also weighted by the average area under the crop in each producing region. Consequently, as a result of the two weighting procedures, a producing region attained more importance the smaller is the estimated standard error of its adoption ceiling and the larger is its area under the coarse cereal.

Data

The analysis was based on secondary district data from a ten-state, time-series data base assembled by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the World Bank largely from the state season and crop reports and statistical abstracts. The time-series spanned 1966–67 to 1983–84.[3]

For each coarse cereal, the production regions correspond to major producing districts which are equivalent to large counties in the United States. A district was included in the sample if it accounted for at least 0.5% of the average total production of the crop during the 1981–82, 1982–83, and 1983–84 agricultural years. Applying this rule gave sample sizes of sixty-six districts for sorghum, sixty for pearl millet, and fifty-eight for maize.

In the early 1980s, the study districts for sorghum and pearl millet accounted for virtually the entire all-India production. The study districts for maize covered only 70% largely because the important maize growing state of Bihar was excluded due to lack of data.

[3] The ten states were Andhra Pradesh, Madhya Pradesh, Karnataka, Tamil Nadu, Maharashtra, Gujarat, Rajasthan, Punjab, Haryana, and Uttar Pradesh.

First-Stage Estimates of Adoption Ceilings

The hypothesis of logistic adoption ceilings received considerable empirical support for both sorghum and pearl millet but not for maize. For sorghum and pearl millet, the estimated ceiling was statistically significant at the .05 level for, respectively, forty-seven (out of 66) and thirty-five (out of 60) districts. Out of those, thirty-nine sorghum districts and nineteen pearl millet districts exhibited a ceiling significantly different from 1.00 (table 2). For maize, the first stage results are characterized by a relatively large number of districts reporting negligible adoption. In general, the logistic did not fit the data that well for many of the maize districts. In districts where adoption was negligible or where the logistic did not converge or did not give a statistically significant estimate of the adoption ceiling, the ceiling estimate was generated by

Table 2. Evidence (in Number of Producing Districts) for Adoption Ceilings of Modern Coarse Cereal Cultivars in India from 1966–67 to 1983–84

	Coarse Cereal		
Adoption Status	Sorghum	Pearl Millet	Maize
Full adoption[a]	8	16	5
Partial adoption and no ceiling[b]	16	20	23
Partial adoption and ceiling[c]	39	19	8
Negligible adoption[d]	3	5	22

[a] Estimated ceiling with a logistic specification greater than 0.90 and statistically significant at the .05 level.
[b] Estimated ceiling with a logistic specification not statistically significant at the .05 level.
[c] Estimated ceiling with a logistic specification less than 0.90 and statistically significant at the .05 level.
[d] The proportion of MC area never exceeded 0.10 during any year in the period of analysis.

averaging the last five years of data in the time series.[4]

Pearl millet districts with a nonsignificant adoption ceiling largely correspond to areas where the first-released pearl millet hybrids became susceptible to downy mildew, resulting in significant economic losses in the early 1970s. In response to those losses, many farmers reverted to local types. In the mid- and late-1970s, hybrid adoption again picked up as farmers accepted the second-generation hybrids which, at that time, were much less susceptible to downy mildew. Therefore, several pearl millet districts had a diffusion curve that better resembled a roller coaster than the conventional S-shape.

In the case of maize, of the thirty-six districts where some diffusion of MCs had occurred, only thirteen were associated with a statistically significant adoption ceiling at the .05 level. The relatively recent release and partial adoption of "second generation" shorter duration MCs in some districts of North India in the early 1980s is a plausible explanation for the poor fit of the logistic to the time-series data from 1966–67 to 1983–84.

A comparative statement of the adoption experience between the modern coarse cereal cultivars and the wheat and rice MCs is made in table 3. For wheat and rice, the ten-state data base is the same as was used for the coarse cereals, and the procedures described earlier were employed to estimate the ceiling levels of adoption.

The contrast between coarse cereal MCs and wheat and rice MCs is marked in table 3. The distribution of the major wheat- and rice-producing districts in the ten-state sample is concentrated in the higher frequencies of more than 50% MC adoption. The coarse cereal districts display a much wider range of diffusion experience.

Coarse cereal MC ceilings approaching full adoption have been confined to specific regions of peninsular India. These eminently successful cases of diffusion of MCs correspond to central Maharashtra where sorghum hybrids are grown in an environment of high production potential, to Gujarat where pearl millet hybrids are widely cultivated, and to regions in South India where maize is nontraditionally produced. Explaining the interregional variation in adoption ceilings is the objective of the next section.

Table 3. Distribution (in Number of Producing Districts) of Estimated Ceiling Levels of Adoption by Cereal

Frequency Range in %	Cereal: Sorghum	Pearl Millet	Maize	Wheat	Rice
<10	11	7	22	0	0
10–25	12	2	9	1	1
26–50	20	13	12	4	7
51–75	13	16	7	9	20
76–90	2	3	1	19	18
>90	8	19	7	34	21
Total	66	60	58	67	67

Second-Stage Model Specification

The explanatory variables, corresponding to the X vector in equations (2), (3), and (4), can be classified into two groups: (*a*) agroclimatic and (*b*) infrastructural variables.

Agroclimatic Variables

The agroclimatic variables reflect the quality of the production environment and the potential sources and incidence of yield reducers on each crop. They were identified from literature reviews and discussions with crop improvement scientists (Jansen).[5]

The agroclimatic variables can be subdivided as follows: (*a*) soil by mean annual rainfall dummy variables, (*b*) growing season monthly rainfall and its variability, for months where prior expectations were strong, and (*c*) other considerations related to the physical and biotic production environment. In general, the soil by rainfall interactions represent the physical quality of the production environment; the monthly rainfall variables are associated with specific types of physical and/or biotic stress.

Expectations regarding the influence of specific yield reducers are based on perceptions on the quality of the production environment (better endowed regions should be more conducive to MC adoption) or on expected differences in tolerance to stress and disease or in growing duration between local varieties and MCs which results in the ability to avoid physical or biotic stress.

[4] For those districts, the standard errors used in the second-stage estimation were also calculated from the last five years of the data series.

[5] A table containing a description of the agroclimatic variables, their sample means and ranges, their expected signs, and associated yield reducers by coarse cereal is available from the senior author upon request.

Average pre-MC yield in the early 1960s is a regressor in the subset of other considerations for each coarse cereal. This variable controls for aspects of the production environment that are not captured by the soil-rainfall interactions or by the monthly rainfall levels or variabilities. *Ceteris paribus,* one expects that higher pre-MC yields are positively associated with MC adoption (Griliches 1957).

Other agroclimatic variables include (*a*) the percentage of rainy season area in the sorghum equation (sorghum MCs have been successfully developed for rainy season cultivation but not for post-rainy season sorghum cultivation) and (*b*) a low rainfall-irrigation interaction because of the high expected productivity of maize in a dry production environment with assured irrigation.

Infrastructural Variables

The infrastructural variables, described in table 4, reflect use of irrigation and access to fertilizer, markets, and roads.[6] In contrast to the agroclimatic variables, they were the same for each coarse cereal.

In the spirit of Boserup; and Pingali, Bigot, and Binswanger, a demographic variable reflecting population pressure on land was also included as a regressor for each coarse cereal. *Ceteris paribus,* a higher ratio of persons to land should be accompanied by increased demand for yield-increasing technical change.

Six models were specified for each of the three cereals; each specification differed in functional form, combination of independent variables, and sample size (Jansen). The nonlinear logit with the additive error structure in equation (4) gave a consistently better statistical fit than either a linear probability or a conventional logit model for all three crops.

[6] Other infrastructural variables (e.g., literacy rate and percentage of villages electrified) were tried in some initial runs of the second-stage estimation. They were highly collinear with the other regressors and did not contribute significantly to the explanatory power of the model. District data on credit or extension infrastructure were not available at the time of the analysis.

Second-Stage Results

Before discussing the second-stage estimated coefficients for each coarse cereal, the overall contribution of the agroclimatic variables and infrastructural variables in explaining the variation in adoption ceilings among major producing districts is considered.

Relative Importance of Agroclimatic and Infrastructural Variables

To test the relative importance of agroclimatic and infrastructural variables, the R^2s are compared for the following three models in table 5: (*a*) an infrastructural model with the independent variables in table 4, (*b*) an agroclimatic model with agroclimatic independent variables, and (*c*) a combined or full model containing both sets of variables as regressors.

The infrastructural variables explain a large share of the interregional variation in MC adoption particularly for pearl millet and maize, but the agroclimatic variables have higher explanatory power. The additional explanatory power of the infrastructural variables in the combined model is not statistically significant at the .05 level with an F-test for both sorghum and pearl millet. Inclusion of the agroclimatic variables to the infrastructural model does lead to significantly enhanced explanatory power for each of the coarse cereals.

Investment in infrastructure has been biased toward the agroclimatically superior regions. This

Table 4. Means of the Infrastructural Variables by Coarse Cereal

Variable	Unit of Measurement	Coarse Cereal: Sorghum	Pearl Millet	Maize
Irrigation	Proportion of cropped area	0.03	0.07	0.28
Fertilizer outlet density	Distribution points/10 km^2	0.35	0.41	0.52
Road density	km of road/10 km^2	3.24	2.68	2.70
Market density	Number of regulated markets/10 km^2	0.02	0.02	0.04
Population	People/ha	2.26	1.82	2.07

Table 5. Proportion of Variation in Estimated Adoption Ceilings Explained by Different Models by Coarse Cereal

	Coarse Cereal		
Model	Sorghum	Pearl Millet	Maize
	($\bar{R}^2$)		
Infrastructural	0.43	0.67	0.78
Agroclimatic	0.80	0.93	0.90
Combined	0.84	0.94	0.95

translates into multicollinearity between the agroclimatic and the infrastructural variables. Such multicollinearity explains why infrastructural variables on their own can explain a substantial part of the variation in adoption ceilings, while at the same time their marginal contribution in the combined model is small.[7]

Sorghum

Rainy season area as a percentage of total sorghum area has the strongest effect on adoption of any of the statistically significant regressors in the sorghum model (tables 6 and 7). Varietal change has been negligible in the postrainy season when sorghum is grown under the relatively assured but low productivity environment of receding soil moisture.

The estimated coefficients of the dummy variables for soil by growing season all tell the same story: too much rain limits the adoption of sorghum MCs. Moving from the reference point of medium black soil and medium rainfall to a higher rainfall regime on black soil is accompanied by a significant fall in the adoption level. Contrary to a priori expectations on drought as a constraint to adoption, switching to a lighter rainfall regime on either medium black, deep black, or red soils results in a significant shift upwards in the estimated ceiling level of adoption. Sorghum in general and MCs in particular are sensitive to water stagnation and to untimely rains favoring pest and disease infestation.

Early growing season rainfall in June also is a significant constraint to the adoption of sorghum MCs. The significance and size of the corresponding coefficient indicate the importance of stand establishment in influencing the adoption of MCs.

[7] Another potential problem consists of a simultaneous equation bias caused by the possibility that infrastructure investments were spurred by the availability of modern cultivars in the favorable areas.

Table 6. Estimated Coefficients and *t*-Values of the Determinants of the Estimated Ceiling Levels of Adoption of Modern Cultivars by Coarse Cereal

Determinants	Estimated Coefficient	*t*-value
	Sorghum	
Agroclimatic		
Deep black soil low rainfall	1.28	2.26
Deep black soil medium rainfall	0.11	0.22
Deep black soil high rainfall	−1.96	−2.88
Medium black soil low rainfall	1.17	2.45
Medium black soil high rainfall	−1.56	−2.78
Red soil low rainfall	2.04	2.76
Red soil medium rainfall	−0.19	−0.36
June rainfall (mm)	0.03	4.13
September rainfall (mm)	0.005	0.63
Annual rainfall (cv)	−0.10	−2.08
June rainfall (cv)	0.015	0.93
September rainfall (cv)	−0.05	−2.88
Rainy season cropping (% sorghum area)	0.06	6.39
Pre-MC yield (tons/ha)	−0.74	−0.46
Infrastructural and Demographic[a]		
Irrigation (% sorghum area)	9.24	2.18
Fertilizer outlet density (distribution points/10 km^2)	2.71	2.33
Population density (people/ha)	−0.54	−2.39
Intercept	−4.98	−2.30
$\bar{R}^2$	0.83	
Correlation[b]	0.80	
Number of observations	66	
	Pearl Millet	
Agroclimatic		
Alluvial soil low rainfall	−0.43	−0.84
Alluvial soil medium rainfall	−0.52	−1.02
Alluvial soil high rainfall	−3.86	−6.87
Black soil low rainfall	3.18	3.24
Black soil medium rainfall	−0.96	−2.04
Black soil high rainfall	−1.18	−1.41
Sandy soil low rainfall	−3.05	−6.47
Sandy soil high rainfall	−0.79	−1.81
June rainfall (mm)	0.019	2.38
July rainfall (mm)	−0.007	−1.89
August rainfall (mm)	0.006	1.67
September rainfall (mm)	−0.017	−3.53
Annual rainfall (cv)	0.09	4.94
June rainfall (cv)	−0.03	−5.17
July rainfall (cv)	−0.07	−5.91
August rainfall (cv)	−0.02	−2.88
September rainfall (cv)	0.035	5.83
Pre-MC yield (tons/ha)	4.04	4.91
Infrastructural and Demographic[a]		
Irrigation (% pearl millet area)	−2.49	−1.75
Fertilizer outlet density (distribution points/10 km^2)	−1.08	−1.50
Population density (people/ha)	−0.53	−2.41
Intercept	3.89	3.71
$\bar{R}^2$	0.95	
Correlation[b]	0.78	
Number of observations	58[c]	

Table 6. Continued

Determinants	Estimated Coefficient	t-value
	Maize	
Agroclimatic		
Alluvial soil low rainfall	−7.76	−1.62
Alluvial soil high rainfall	−5.66	−2.10
Black soil low rainfall	1.65	0.63
Black soil medium rainfall	4.87	3.51
Black soil high rainfall	5.22	2.92
Sandy soil low rainfall	1.28	0.82
Sandy soil medium rainfall	4.22	3.96
Sandy soil high rainfall	−4.75	−2.83
July rainfall (mm)	0.008	2.73
August rainfall (mm)	−0.02	−3.80
Annual rainfall (cv)	−0.13	−3.64
June rainfall (cv)	0.007	0.66
Dry and irrigated	10.42	2.05
Pre-MC yield (tons/ha)	−0.57	−0.77
Infrastructural and Demographic[a]		
Irrigation (% maize area)	−1.69	−0.97
Fertilizer outlet density (distribution points/10 km^2)	5.26	5.44
Market density	2.66	0.34
Road density	0.34	2.35
Population density	0.16	0.42
Intercept	−1.93	−1.35
$\bar{R}^2$	0.95	
Correlation[b]	0.95	
Number of observations	58	

[a] The road and market density variables were dropped from sorghum and pearl millet second stage analysis because they were statistically insignificant and were collinear with several of the other regressors.
[b] Pearson correlation coefficient between actual and predicted values.
[c] The Tamil Nadu districts of South Arcot and Tirichurapalli were excluded because they rely heavily on the Northeast monsoon which is not active in other millet-growing regions.

Table 7. Elasticity Values of Significant Regression Variables

Variable	Coarse Cereal: Sorghum	Pearl Millet	Maize
Agroclimatic			
Deep black soil low rainfall	0.31		
Deep black soil high rainfall	−0.47		
Medium black soil low rainfall	0.28		
Medium black soil high rainfall	−0.37		
Red soil low rainfall	0.49		
Alluvial soil high rainfall		−0.90	
Black soil low rainfall		0.74	
Black soil medium rainfall		−0.22	
Sandy soil low rainfall		−0.71	
Alluvial soil low rainfall			−1.71
Alluvial soil high rainfall			−1.24
Black soil medium rainfall			1.07
Black soil high rainfall			1.15
Monthly Rainfall (mm)			
June	2.28	0.48	
July		−0.47	1.33
August		0.33	−2.91
September		−0.66	
Rainfall Variability (cv in %)			
Annual	−1.49	1.11	−2.45
June		−0.93	
July		−1.35	
August		−0.51	
September	−1.72	1.04	
Other Agroclimatic			
Rainy season cropping (%)	2.46		
Pre-MC yield (tons/ha)		0.64	
Infrastructural			
Irrigation (proportion of cropped area)	0.19		2.91[a]
Fertilizer availability (distribution points/10 km^2)	0.56		1.84
Road density (km of road/10 km^2)			0.61

Note: Elasticity values for continuous variables in logistic-based models equal $bx(1 - y)$, where b is the estimated regression coefficient, x the regressor value, and y the estimated ceiling value. Elasticities were evaluated at arithmetic means of the variables. For the soil-rainfall dummy variables the reported figures are simple marginal coefficients which equal $by(1 - y)$.
[a] Dry districts only.

Regions with more variable September rainfall are also less likely to adopt sorghum MCs than other producing zones. Because sorghum MCs are usually harvested before the monsoon recedes in October and rainfall just before harvesting favors the development of grain mold and earhead pest infestations, sorghum MCs should be more affected by rainfall variability in September than the later-maturing, photoperiod-sensitive local varieties.

The infrastructural variable with the strongest effect on sorghum MC adoption is the density of fertilizer distribution points. Under good rainfall conditions, sorghum MCs can be highly responsive to fertilizer. Irrigation is also statistically significant although its effect on adoption is relatively small.

The negative and significant coefficient of the person-to-land ratio in table 6 is also contrary to a priori expectations. The importance of sorghum as a fodder could explain this finding. The demand for milk, particularly in urban areas, is high in India, and sorghum stover is widely fed to dairy cattle. Because local varieties produce more fodder and less grain per plant, they might be preferred in areas where the urban demand for milk fuels rising stover to grain price ratios (Walker).

Pearl Millet

Explanations for the interregional variation in MC adoption in pearl millet centered on the levels and variability in monthly rainfall. Six of the eight monthly rainfall-related regressors are sta-

tistically significant in table 6. Variability in June, July, and August rainfall, associated with early, mid-, and end-of-season drought, have a negative impact on the ceiling level of adoption. More abundant early season rain in June should result in improved stand establishment and, as expected, June rainfall was signed positive. Heavier rain later in the season should foster panicle diseases and, as expected, was signed negatively.

The significant results for the variabilities in annual rainfall and in September rainfall are inconsistent with a priori expectations. Those results imply that *ceteris paribus,* the adoption of pearl millet MCs is greater in more variable annual and September rainfall conditions. Perhaps these results attest to the robust character of pearl millet MCs which suffer from fewer yield reducers than either maize or sorghum MCs. Shorter duration pearl millet MCs may also better escape variable drought stress in September than longer duration locals.

Three of the eight soil by growing season rainfall regions have adoption ceilings significantly different from the benchmark sandy soil, medium rainfall region. In the dry sandy soil, low rainfall region comprised mainly of Rajasthan, pearl millet MCs have made limited headway. Districts with heavier black soil and low rainfall represent a high potential production environment for pearl millet hybrids. Waterlogging limits the profitability of pearl millet hybrids in districts with alluvial soils and high rainfall.

Unlike sorghum and maize, pre-HYV millet yields do contribute significantly to explaining the interregional variation in MC adoption. Net of the included climatic, soil, and infrastructural variables, districts with heavier pearl millet yields before the MCs were released also had higher levels of adoption.

Consistent with the sorghum result, population density significantly and inversely affects adoption. The urban demand for milk may apply equally well for pearl millet as for sorghum.

Maize

The results for maize were more sensitive to model specification. Infrastructural variables, particularly fertilizer, loomed larger in explaining interregional variation in adoption than for sorghum and pearl millet. Unlike the sorghum and pearl millet hybrids, the maize MCs are mostly of longer duration than local varieties, and they may not fit as well in farmers' cropping systems. In general, the yield differences of the MCs over the local varieties are less for maize than for sorghum or millet. Maize is also less drought tolerant, more responsive to inputs, and less susceptible to panicle diseases than the other two coarse cereals. Thus, the size and significance of the fertilizer density variable and the low rainfall-irrigation binary variable is consistent with a priori expectations.[8] Because more maize is marketed than sorghum and millet, a finding of the significant bearing of road density on adoption is also not surprising.

Similar to the results for millet, too much or too little water can erode productivity and incentives for MC adoption. Within production regions, mainly in North India, where alluvial soil is common, both the high and low rainfall districts are inferior in adoption performance to the more moderate rainfall regions. Excess rainfall can also be a problem in the sandy soil regions but does not appear to be a constraint to adoption in the nontraditional, predominantly black-soil, maize-producing belt in South India.

A positive and significant estimated coefficient on July rainfall and a negative and significant coefficient on the variability of annual rainfall indicate the presence of drought as a yield reducer. More support from drought as a yield reducer comes from the linear logit specification (not reported) where the coefficient of the variability in June rainfall was signed negatively and significant.

The negative influence of August rain on MC adoption is attributed to waterlogging and stalk rot, which is a problem in areas of higher rainfall during the early August preflowering period. In some years, shorter duration local varieties can escape the adverse consequences of excess rainfall in August.

Implications and Conclusions

This study finds evidence for (*a*) ceiling levels of adoption, (*b*) the importance of agroclimatic variables relative to infrastructural considerations in conditioning those ceilings, and (*c*) the use of diffusion analysis of secondary data to

[8] In order to separate out the effect of irrigation in "dry" maize districts (annual rainfall < 750 mm) and "wet" maize districts (annual rainfall > 750 mm), a new variable was created consisting of the product of a dummy variable (equaling one for dry districts and zero otherwise) and a variable measuring the percentage of irrigated maize area. The effect of irrigation on the adoption ceiling is then measured by the sum of the estimated coefficients of the newly created variable and the irrigation variable for dry districts and by the coefficient of the irrigation variable for the wet districts.

shed some light on priorities for agricultural research in coarse cereals to shift the adoption ceilings.

For agroclimatic variables, excess moisture significantly influences adoption of coarse cereal MCs in some producing regions. Sorghum in particular is highly susceptible to rainfall-induced disease and pest infestations. While early season drought can curtail MC adoption, the possible influence of mid- to end-season drought on adoption ceilings was not supported empirically. Thus, except for the sandy soil, low rainfall pearl millet growing regions and the post-rainy sorghum growing belt, the findings suggest that early season moisture stress warrants higher priority in drought research than mid- to late-season stress.

For infrastructure, the inverse relationship between population pressure and the ceiling levels of sorghum and pearl millet MC adoption suggests that more weight should be given to fodder as an end use in MC development.

The findings also indicate that expanding and deepening input and output market infrastructure alone are unlikely to substantially increase the present adoption ceilings. Qualitatively different MCs from those now released appear necessary to change regional adoption behavior. Fertilizer availability, especially for sorghum and maize, was the most important infrastructural variable in explaining interregional variation in MC adoption. The significance of the dummy variables for soil by growing season rainfall associated with excess moisture also suggest that investment in drainage could stimulate adoption of MCs in some producing districts.

The results highlight the importance of regionally specific production conditions in crop improvement research in India. The past emphasis on wide adaptation in breeding research has stimulated aggregate productivity growth and aided in identifying the regions of higher production potential. With growing private sector research on coarse cereal hybrids (Pray et al.), the public sector could reallocate its resources to more location specific and difficult problems of the lagging adoption regions. In addition, as suggested by the results for maize, the total cropping system rather than individual crops should be emphasized.

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Household Inventories and Marketed Surplus in Semisubsistence Agriculture

Mitch Renkow

A model of semisubsistence agriculture explicitly accounting for the ability of farm households to hold inventories of staple foods is developed. Comparative statics analysis highlights the potential importance of wealth effects attributable to price-induced changes in the value of household inventories. Empirical results for three groups of households in an Indian village confirm that failure to account for household inventories leads to an overstatement of the responsiveness of both consumption demand and marketed surplus.

Key words: agriculture household model, inventories, marketed surplus.

A notable feature of nearly all developing countries is that most agricultural households produce a significant portion of the staple foods that they consume. This is the case for a wide cross section of geographical locations, levels of technological advancement, and land tenure arrangements. How these semisubsistence households allocate output of staple foods between home consumption and market sales is an issue that has received considerable attention from economists because of its important implications for aggregate market supply, food disappearance patterns, and the attendant nutritional consequences for rural and urban dwellers.

A major focus of past research has been measuring the response of marketed supply (or marketed surplus) to changes in prices and other exogenous variables. Most analyses begin by positing an identity that sets marketed surplus equal to the difference between output and consumption (Behrman, Haessel). Differentiating this identity then yields an expression for the price elasticity of marketed surplus as a function of the price and income elasticities of consumption and the price elasticity of total output. Recently, Strauss (1984, 1986) has made an important contribution to this literature by explicitly recognizing the wealth effects on consumption resulting from the impact of price changes on farm profits. His theoretical work demonstrates that under certain circumstances these wealth effects may be large enough to induce positive own-price demand response and negative marketed surplus response.

The point of departure for this paper lies in the omission of household storage of staple foods from existing research on semisubsistence households. Implicitly, all work to date has assumed that households costlessly store exactly the amount allocated to home consumption over the period between harvests. Arguably, this is a relatively harmless simplification, especially if the marginal cost of storage is low. A more serious conceptual problem, however, is that existing models take consumption, output, and sales as occurring simultaneously. A change in the price of a commodity that is produced by the household thus affects marketed surplus through its impact on both contemporaneous consumption and production. Within a given cropping cycle, this is not normally the case; rather, the output from which marketed surplus is drawn is predetermined and exists as currently held inventories and/or recent harvests. Stocks on hand and expected future output are likely to influence short-run marketing decisions, but only through wealth effects on consumption. Even in the long run, when output can adjust to price movements, these wealth effects may still significantly affect marketed supply response.

Two factors may motivate semisubsistence

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households to hold inventories of staple foods. First, households might want to minimize their reliance on local markets for the satisfaction of basic food needs, holding stocks of food as a contingency against unanticipated supply disruptions. Second, inventories of home-produced staples might result from profit-seeking behavior in response to seasonal price movements for a particular storable commodity. Subject to storage costs and on-farm storage capacity, such arbitrage opportunities could influence the timing of market sales.[1]

In the next section, a simple model of the economic behavior of semisubsistence farm households is developed. The model follows in the tradition of the household-firm literature (Jorgensen and Lau, Barnum and Squire), but it is distinguished from previous work by its recognition of the ability of households to store important consumption items (specifically, staple foods). The model's solution highlights the importance of expected future prices as arguments of both inventory and commodity demand functions, and yields a simple inventory demand equation which provides an empirically tractable way of distinguishing between different motives for holding stocks. Expressions for short- and long-run response of demand for and marketed surplus of storable commodities are then derived. These differ considerably from comparable expressions found in the literature. In particular, it is shown that as long as household inventories are nonzero, the earlier methods will have overstated the own-price elasticities of both demand and marketed surplus.

The empirical analysis is directed at estimating these elasticities and comparing them with those computed using more traditional methods. Econometric results are presented for three groups of households in a poor West Indian village in which stocks of grain comprise a significant share of household wealth. The results provide evidence that inventories of staple foods can indeed have important effects on the own-price response of both demand and marketed surplus, primarily through wealth effects on consumption. Finally, a comparative analysis confirms that by failing to account for the role of inventories, earlier methods systematically overstated the own-price elasticities of both demand and marketed surplus for stored commodities.

[1] A referee points out that an additional motive for holding inventories is a household's desire to diversify its portfolio of savings assets. Such a savings motive is related to the first motive discussed above in that both stem from a desire to minimize risk.

An Agricultural Household Model with Storage

Consider a representative semisubsistence household that produces a single storable food commodity (X_1) that is either consumed or traded for one other (composite) commodity (X_2). Utility is derived solely through the consumption of the two goods and leisure (X_L),[2] with the one-period household utility function given by

$$(1) \qquad U_t = U(X_{1t}, X_{2t}, X_{Lt}),$$

where $U(\cdot)$ is twice-differentiable, continuous, quasi-concave, and intertemporally strongly separable. The household is assumed to maximize the expected (discounted) value of a stream of current and future utilities up to the end of the current cropping cycle. Each cropping cycle is composed of $T + 1$ periods $(0, \ldots, T)$, extending from harvest to harvest, and cycles overlap in the sense that period T of one coincides with period 0 of the next.

At the beginning of each cropping cycle the quantity Q_o is harvested. In each period, the household sells or buys the quantity M_t at price P_{1t} (positive for sales, negative for purchases), consumes an amount X_{1t} of the produced commodity, and purchases an amount X_{2t} of the alternate commodity at price P_{2t}. The portion of marketable surplus not sold or consumed in a given period must be stored. Disappearance of the produced commodity in period t is governed by the stock identity[3]

$$(2) \qquad I_t - I_{t+1} + Q_t = X_{1t} + M_t,$$

where I_t and I_{t+1} are carryin and carryout inventory levels, respectively, and Q_t is output of the produced commodity in period t. Output is modeled as certain, with production assumed to depend only on one variable input (labor) and one fixed factor (land):[4]

$$(3) \qquad Q_T = Q(L_o, \ldots, L_{T-1}; A_o),$$

where L_t denotes total labor used by the household in period t (both family and hired) and A_o

[2] The model can be expanded easily to include vectors of storable and nonstorable commodities, cash crop production, and production of nonstorable foods. However, the "bare-bones" model presented here is sufficient to illustrate the salient points.

[3] Storage losses are ignored here because they do not substantively affect the behavioral implications of the first-order conditions. Assuming proportional losses has an effect identical to lowering the household's subjective rate of time preference (Wohlgenant, p. 740).

[4] See Roe and Graham-Tomasi for a treatment which introduces production risk into an agricultural household model.

is the household's fixed quantity of land. By definition, $Q_t = 0$ for $t = 1, \ldots, T - 1$.

Assume that the one-period cost of carrying inventories from period t to period $t + 1$ is given by

$$(4) \quad C(I_{t+1}, X_{1t}) = a_o + {}^1\!/_2 f^{-1} \cdot (I_{t+1} - g_o - gX_{1t})^2,$$

where a_o, f, g_o, and g are parameters assumed to be positive. This specification, discussed in Holt et al. and Belsley and more recently employed by Wohlgenant, posits inventory costs as composed of two offsetting components. The first is the physical cost of holding stocks, which is increasing in I_{t+1}. The second is a convenience yield, expressed as a linear function of consumption. In the production-oriented inventory literature this latter component typically refers to the opportunity cost of stock-outs and back-ordering. Here the emphasis is on consumption, but the logic is the same: convenience yield is the value to the household of being able to meet demand for the storable commodity from its own stocks.[5] Thus, convenience yield from household inventories is similar to the benefits attributed to liquidity in the savings literature.

In the context of semisubsistence agriculture, the cost of stocking out likely rises more steeply than the physical cost of holding inventories. This certainly would be the case if a market for the stored commodity were absent, as then stocking out would mean doing without. Alternatively, the existence of covariate production risk over a large geographical area—a feature characteristic of rainfed agriculture in many locations—would cause the marginal cost of stocking out to be high, even in the presence of complete markets. In this event, an individual household's poor harvest would be correlated with diminished aggregate supply (and attendant higher prices).

The preceding discussion is illustrated in figure 1. Inventory holdings are plotted on the x-axis and costs on the y-axis. For positive inventory holdings, storage costs rise in proportion to the quantity held. To the left of the vertical line that indicates zero inventories, the cost of not

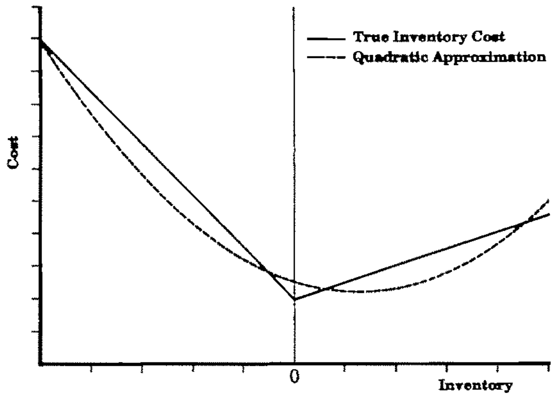

Figure 1. Quadratic approximation of inventory cost

having stocks on hand to meet demand rises more steeply. The quadratic specification of equation (4), shown as a dotted line, approximates the true inventory cost function.[6]

Sources of cash income for the household include sales of agricultural output, off-farm labor earnings (at a wage P_{Lt}), and exogenous non-wage income (Y_t). Households can also borrow any amount B_t at a one-period interest rate r.[7] Household expenditures consist of commodity purchases, storage costs, production costs, and loan repayments. Thus, in each period the household faces a budget constraint given by

$$(5) \quad P_{1t}M_t + P_{Lt}(F_t - L_t) + Y_t + B_t = P_{2t}X_{2t} + C(\cdot\,,\cdot) + (1 + r)B_{t-1},$$

where F_t is family labor. If $F_t - L_t > 0$, then the household is a net supplier of labor to the market (and vice versa).

It is assumed that markets exist for all commodities and labor, that the household is a price taker in these markets, and that hired and family labor are perfect substitutes, thus insuring that the model is recursive (Barnum and Squire). To complete the model, a time constraint states that in each period the total time available to the

[5] Implicit in the inventory cost function specified in equation (4) is the notion of negative inventories. This is equivalent to back-ordering and stock-out costs as treated in conventional inventory models. In the present context, it may be rationalized by noting that semisubsistence households often have access to in-kind credit markets whereby grain will be borrowed in lean periods and repaid at harvest time. Thus, household consumption may exceed market purchases even when no stocks are carried over from a previous period without violating the stock identity of equation (2).

[6] Another interpretation is that the quadratic approximation simplifies fixed costs of entry into the market—i.e., a jump when the slope of the true inventory cost schedule shifts from positive to negative. If true, this would invalidate the recursiveness of the model, by endogenizing output price.

[7] The assumption of perfect credit markets, while nearly universal in this class of models, is often dubious. While all households in the village considered in this study do have access to some form of credit, there is evidence of segmentation between formal and informal credit markets and equilibrium rationing (Binswanger et al).

household (T^*) is devoted to either leisure (X_{Lt}) or labor:

(6) $$T^* = X_{Lt} + F_t.$$

Equations (1)–(6) define an optimization problem to be solved in each period by the household. To obtain a solution to this problem, first solve (2) for M_t and (6) for F_t. Next, substitute these and (3) into the budget constraint and form the Lagrangian

(7) $$\underset{z}{\text{Max}}\, E_t \sum_{s=t}^{T} b^{s-t}\{U(X_{1s}, X_{2s}, X_{Ls}) + \lambda_s[P_{Ls}(T^* - X_{Ls} - L_s) + P_{1s}(Q_s + I_s - I_{s+1} - X_{1s}) + B_s + Y_s - P_{2s}X_{2s} - C(I_{s+1}, X_{1s}) - (1 + r)B_{s-1}]\},$$
$$Z = (X_{1t}, X_{2t}, X_{Lt}, I_{t+1}, B_t, L_t).$$

Here $b = (1 + r)^{-1}$ is the discount rate (assumed constant) and E_t denotes a mathematical expectation conditional on information Ω_t available at time t. Ω_t is assumed to include all current and past values of the control variables in Z and prices.

Differentiating (7) with respect to the control variables yields the following first-order conditions for any period t:[8]

(8) $$U_{1t} - \lambda_t(P_{1t} + C_x) = 0$$

(9) $$U_{2t} - \lambda_t P_{2t} = 0$$

(10) $$U_{Lt} + \lambda_t P_{Lt} = 0$$

(11) $$bE_t(\lambda_{t+1}P_{1t+1}) - \lambda_t(P_{1t} + C_I) = 0$$

(12) $$E_t(\lambda_t - \lambda_{t+1}) = 0$$

(13) $$b^{T-t}E_t P_{1T}(\partial Q_T/\partial L_t) - P_{Lt} = 0$$

plus the budget constraint. Here, C_I and C_X denote the partial of the inventory cost function with respect to I_{t+1} and X_{1t}, respectively, and λ_t is the marginal utility of period t income.[9]

Given the inventory cost function [equation (4)], equations (11) and (12) imply that optimal inventory holdings will be a linear function of the difference between the current and (discounted) expected value of the next period's price for the stored commodity and the household's demand for the commodity in the current period. Substituting (4) and (12) into (11) and rearranging:

(14) $$I_{t+1} = g_o + f \cdot \Delta P_t + g \cdot X_{1t},$$

where $\Delta P_t = bE_tP_{1t+1} - P_{1t}$. A natural interpretation of the f and g parameters is that they indicate the strength of arbitrage and food security motives for holding inventories discussed earlier.

Equations (8)–(10) yield the standard result that at the optimum the marginal rate of substitution between any pair of goods (including leisure) will equal the ratio of the prices of those goods.[10] Equation (13) provides another standard result, namely, that the optimal allocation of labor into the production process is such that the (expected) value of its marginal product equals the wage rate. This result also highlights the recursiveness of the model in that none of the demand-side control variables appear in (13).

Comparative Statics

Short-Run Response

The model developed above treats the timing of the household's economic activity over the cropping cycle more carefully than previous work. In particular, the assumption that production, consumption and sales occur simultaneously has been abandoned. Instead, the present analysis recognizes that the output from which marketed surplus is drawn by the household is predetermined, existing as currently held inventories and new production. This has implications for marketed surplus response.

Differentiating (2) with respect to P_{1t} (and noting that within the cropping cycle $dQ_t/dP_{1t} = dI_t/dP_{1t} = 0$)

(15) $$\frac{dM_{1t}}{dP_{1t}} = -\frac{dX_{1t}}{dP_{1t}} - \frac{dI_{t+1}}{dP_{1t}}.$$

[8] It is assumed that the random disturbances of the forcing variables in (7) are normal with zero means. This insures that first-order certainty equivalence holds (Malinvaud), allowing the optimization problem to be solved as if no uncertainty existed.

[9] The result that $E_t\lambda_{t+1} = \lambda_t$—i.e., that the marginal utilities of current and expected income are equal—is derived somewhat differently by Browning, Deaton, and Irish in the context of a life-cycle model of labor supply. Here, it hinges on the assumption that the utility rate of time preference equals the rate of interest on borrowed funds.

[10] A referee points out that the assumption of intertemporally separable utility implies that, conditional on current period expenditure, prices in other periods affect current demands only via changes in total expenditure over the entire planning horizon. Insofar as periods are defined in terms of seasons, this could be problematic if seasonality in prices or consumption is important. In the area under study, however, no seasonality in prices was observed (see footnote 16), and t-tests revealed no significant differences in mean consumption between seasons for any group of households considered (Renkow, p. 76).

From equation (14),

$$(16)\quad \frac{dI_{t+1}}{dP_{1t}} = \frac{\partial I_{t+1}}{\partial E_t P_{1t+1}} \cdot \frac{dE_t P_{1t+1}}{dP_{1t}} + \frac{\partial I_{t+1}}{\partial P_{1t}} + \frac{\partial I_{t+1}}{\partial X_{1t}} \cdot \frac{\partial X_{1t}}{\partial P_{1t}} = -f\left(1 - b \cdot \frac{dE_t P_{1t+1}}{dP_{1t}}\right) + g \cdot \frac{dX_{1t}}{dP_{1t}}.$$

Thus, the response of marketed surplus to a contemporaneous price change is given by

$$(17)\quad \frac{dM_t}{dP_{1t}} = -(1+g) \cdot \frac{dX_{1t}}{dP_{1t}} + f\left(1 - b \cdot \frac{dE_t P_{1t+1}}{dP_{1t}}\right).$$

Because the effect on expected future price of a change in the current price will in general be positive and no greater than unity, the sign of dM_t/dP_{1t} depends on the price responsiveness of consumption.

The first-order conditions imply that the Marshallian demand for the produced commodity may be written as

$$X_{1t} = X(P_{1t}, P_{2t}, \hat{P}_{1t+1}, W_t),$$

where

$$W_t = Y_t + \left[P_{1t}S_t + b^{T-t}E_t\left(P_{1T}Q_T - \sum_s P_{Ls}L_s\right)\right] + P_{Lt}T^* = Y_t + \Pi_t + P_{Lt}T^*.$$[11]

Here, W_t is an expression for the household's period t wealth that includes exogenous income, expected net revenue from production over the planning horizon (π_t), the value of stock on hand ($P_{1t} \cdot S_t$, where $S_t = I_t + Q_t$), and the value of household time.[12] The effect of a change in P_{1t} on current consumption may then be written as

$$(18)\quad \frac{dX_{1t}}{dP_{1t}} = \left.\frac{\partial X_{1t}}{\partial P_{1t}}\right|_{d\Pi = 0} + \frac{\partial X_{1t}}{\partial \Pi_t} \cdot \frac{d\Pi_t}{dP_{1t}} = \left.\frac{\partial X_{1t}}{\partial P_{1t}}\right|_{dU = 0} - X_{1t} \cdot \frac{\partial X_{1t}}{\partial W_t} + \left(S_t + \hat{Q}_T \cdot \frac{d\hat{P}_{1T}}{dP_{1t}} + \hat{P}_{1T} \cdot \frac{\partial \hat{Q}_{1T}}{\partial \hat{P}_{1T}} \cdot \frac{\partial \hat{P}_{1T}}{\partial P_{1t}}\right) \cdot \frac{\partial X_{1t}}{\partial W_t}.$$

This analysis bears a strong resemblance to that of Strauss (1986) in its explicit recognition of wealth effects induced by a price change. In addition to the usual substitution and income effects of a conventional Slutsky equation (the first two terms of the second equality), consumption also depends on an extra wealth effect (or profit effect in Strauss' parlance) that is a function of stocks on hand, expected future output, and the mechanism by which the household forms price expectation.[13] It is therefore possible that the overall response to a price increase might be positive if this wealth effect is sufficiently large.

Long-Run Response

The comparative statics in the previous section yielded expressions for uncompensated demand and marketed surplus response in the short run when output is fixed. Previous work has tended to emphasize long-run (or steady-state) marketed surplus response.[14] In the context of the model developed above, consideration of long-run effects shifts the focus from analyzing the impact of exogenous shocks (e.g., price changes) within the cropping cycle to analyzing impacts across cycles. In particular, steady-state output will adjust to current price changes and thus long-run marketed surplus response will be more elastic.[15]

[11] For notational simplicity, "^" will hereafter be used to denote the appropriately discounted conditional expectation formed in period t.

[12] In actuality, the discounted expected value of all future net revenue ought to be included here. A reasonable argument for truncating this infinite stream at the end of one planning horizon is that discounting reduces the present value of net revenue from subsequent cropping cycles to an insignificant magnitude.

[13] Note that to the extent that expected input prices (especially wages) adjust to changes in the current output price, the profit effect in (18) is incomplete. Because a positive relationship between P_t and, say, the expected wage rate is likely to exist, the profit effect would be smaller than depicted in (18) for net purchasers of labor (e.g., large farms) and larger than depicted in (18) for net sellers of labor (in many instances, small-farm households).

[14] The analysis in this section owes substantially to comments made by John Strauss on an earlier draft of this paper.

[15] In addition to direct price response of output, one might postulate indirect effects via induced investment. Such indirect effects are ignored here.

Derivation of long-run marketed surplus response stems from the observation that in the steady-state inventory changes go to zero (i.e., $dI/dt = 0$). A steady-state version of the identity in equation (2) is thus given by

$$(2') \qquad M^* = Q^* - X^*,$$

where asterisks denote steady-state values and the subscript denoting the commodity has been dropped. This identity is formally identical to that traditionally used in derivations of marketed surplus elasticities and implies that long-run marketed surplus response is of the form

$$(17') \qquad \frac{dM^*}{dP_{1t}} = \frac{dQ^*}{dP_{1t}} - \frac{dX^*}{dP_{1t}}.$$

Equation 17′ differs from the expression for short-run marketed surplus response derived above in two important ways. First, it directly accounts for output response to price. Because output is fixed in the short run, (expected) output response has only an indirect effect on marketed surplus response via wealth effects in consumption, as in equation (18). When output is free to vary, output response enters the equation directly as well.

Second, because steady-state inventory is constant, the parameters associated with the price response of inventories disappear. As in the short run, however, long-run response of consumption is expected to depend in part on the wealth effect of price changes due to changes in the value of household inventories. This additional wealth effect distinguishes the analysis developed in this paper from earlier approaches. As long as household inventories are nonzero, this stock effect implies that both consumption demand and marketed surplus will be less elastic than previous analyses have indicated.

The Data

For the empirical analysis, inventory and consumption demands were econometrically estimated using panel data from a West Indian village collected between 1976 and 1983 as a part of the "Village-Level Studies" project of the International Crops Research Institute for the Semi-Arid Tropics (Singh, Binswanger, and Jodha). Shirapur, the village considered, is a poor and extremely drought-prone village located in the semiarid tropics of India. It is dependent on agriculture, with crop production and agricultural labor providing the bulk of household income. Most farm households in the village satisfy a large part of their demand for the predominant dietary staple (sorghum) through their own production. Sorghum is the dominant crop, occupying over 50% of total cropped area on average. Given the harshness of the village's agronomic environment, relatively few cash-cropping alternatives are available.

Monthly data on agricultural production, consumption, and market transactions were organized on a quarterly basis. These data, in conjunction with annually collected inventory data, provided a complete record of the sources and uses of the various commodities consumed. Quarterly inventory schedules of the most important staples stored by households were then derived by subtracting consumption and sales (including in-kind payments) from production and purchases (including in-kind receipts).

Except for nonfood items, quarterly price data were derived by taking the arithmetic means of the ratio of value and quantity for all transactions involving a particular commodity. Where more than one commodity was aggregated, individual prices were weighted by their mean expenditure shares over the entire sample. All prices were then deflated by village-specific consumer price indices reported in Walker et al. For nonfood items, a statewide price index reported by Walker et al. was used.

Table 1 presents summary statistics on average quarterly consumption, inventory holdings, and marketed surpluses of stored grains in Shirapur. Inventories tend to be large relative to consumption in the village, with mean quarterly inventories exceeding mean quarterly consumption for all farm-size classes.

Econometric Considerations

Measuring the own-price elasticities of demand and marketed surplus for stored commodities required estimates of the parameters of output supply response, inventory demand, and consumption demand. The econometric strategy consisted of separately estimating inventory demand equations [of the form suggested by equation (14) above] and systems of commodity demand equations for each of three farm-size classes within the village. The estimated demand-side parameters were then combined with existing estimates of the parameters of output supply in order to compute own-price elasticities of de-

Table 1. Quarterly Consumption, Inventories, and Marketed Surplus of Stored Commodities by Farm Size

	Consumption		Inventory		Marketed Surplus	
Farm Size[a]	Mean[b]	C.V.[b]	Mean[b]	C.V.[b]	Mean[b]	C.V.[b]
Small	210.0	29.0	247.2	51.9	62.3	248.2
Medium	297.8	23.0	413.9	38.6	133.3	82.0
Large	386.7	28.3	631.5	36.8	84.3	227.3

[a] These use the classification system employed by ICRISAT and defined as follows: small farms: 0.21–2.50 hectares; medium farms: 2.51–5.25 hectares; large farms: >5.25 hectares.
[b] These are quarterly household means (in kilograms) and coefficients of variation across individual household means expressed in percentage terms.

mand and marketed surplus for stored commodities.

Eight years of quarterly inventory data were available for thirteen households in Shirapur. Large quantities of sorghum and wheat were stored by all of these households during at least a portion of each crop year. Preliminary analysis revealed that the prices of wheat and sorghum were highly correlated. For this reason, these were combined into a "grains" aggregate. Pretest estimation indicated that the inventory data satisfactorily supported grouping the households into small, medium, and large farm-size classes, but that the data did not support pooling across farm-size classes. The household data were thus pooled for each farm-size class, and fixed effects models were estimated by two-stage least squares, using the price of sorghum and the nonfood price index as instruments for X_{1t}.

Univariate ARMA forecasts were used to generate one-period-ahead expected prices. The price of grain in Shirapur was best represented by an AR1 model.[16] As a check on the consistency of the estimator using ARMA price forecasts, Wu-Hausman tests were conducted to compare this with an alternative estimator which was known to be consistent. The alternative was an instrumental variable (IV) estimator in which the realized future price was used in the construction of ΔP_t and the ARMA forecast price was used as an instrument. Where the consistency of the estimates using the ARMA estimator was rejected, the results from the use of the IV estimator will be reported.

[16] The price of stored grain did not follow the saw-toothed seasonal pattern one might normally expect for annually harvested crops. Rather, the model which best represented the data—$P_t = 0.183 + 0.844\, P_{t-1} + \varepsilon_t$—was empirically indistinguishable from a random walk. This may result from the success of government price stabilization policies, coupled with the relatively free flow of grain across regions.

Consumption Demand

Commodity demand systems were estimated by farm-size class for each village using a Rotterdam model. An important reason for choosing the Rotterdam model over other functional forms was that it eliminated the need to explicitly model household-specific characteristics (as these are effectively differenced out of the data), thereby greatly simplifying the econometric procedures. Commodities included as dependent variables in the analysis were stored grains, nonstorable home-grown foods, and commodities procured exclusively from the market. Leisure was assumed to be weakly separable from the other arguments of the utility function, thereby eliminating the necessity of estimating labor supply as part of the system. The theoretical model developed above indicated that the appropriate independent variables in the system included all contemporaneous prices, household wealth (including the value of stocks on hand and the expected value of future output), and the expected prices of stored commodities one period in the future.

The wealth variable used on the right-hand side of the estimating equations ($\Delta\log Y^*$) was that suggested by Deaton and Muellbauer:

$$Y^* = \Delta\log Y - \sum_k \omega_k \Delta\log P_k,$$

where Y is total expenditure and the ω_k's are expenditure shares. The quantity Y^* represents the proportional change in real total expenditure—an index of real income. Given the way in which the data were constructed, Y included the value of stocks on hand. Thus, Y^* incorporated all contemporaneous real income flows. An intercept term was included to account for expected net revenues from future production. Finally, the

theoretical model indicated that commodity demands depend also on the (one-step-ahead) expected price of stored commodities. Since the price of grain was found to follow an AR1 process, however, it was not necessary to include lagged price terms in the reduced-form equations.

The individual commodity demand equations were estimated as a system of seemingly unrelated regressions. Significant serial correlation was evident in the individual demand equations, and was corrected using a Cochrane-Orcutt procedure. Given the construction of the real income variable, adding-up was automatically imposed on the system. Because all prices and the expenditure variable were deflated by a common price index, homogeneity was implicitly imposed. Finally, because of the inclusion of inventories in the model, the Hessian matrix of second derivatives is not symmetric. Hence, symmetry was neither imposed nor tested in the estimation.

Eight of the twenty-seven price coefficients were significant at the 10% level or better, and nearly all income coefficients attained the 1% significance level. Most constants were insignificant, and those that were significant were quite small. A complete listing of the parameter estimates is available from the author upon request.

Income and compensated price elasticities implied by the regression results are found in table 2. In most cases, own-price elasticities of the stored commodities are smaller in magnitude than those of the other commodity groups. In several instances, cross-price elasticities indicate some complementarity among commodities.

Income elasticities are all positive, which is expected at this level of aggregation. The income elasticities of the stored commodities are strikingly smaller than those for other commodity groups in all instances. This relationship between the income elasticities of grains and other commodities in Shirapur was also found by Sharma. In contrast, Behrman and Deolalikar found the opposite pattern. However, their empirical estimates were for a sample drawn from three villages (one of which was Shirapur) located in distinctly different agroclimatic zones of semiarid tropical India. Additionally, they pooled the data from all farm-size classes (including landless households).

Uncompensated own-price elasticities of demand for stored grains were calculated using the formula derived above. Crop years were split into two periods—the two quarters immediately preceding harvest (the "lean season") and the two quarters immediately following harvest (the "harvest" season)—and elasticities were evaluated at the quarterly means for each season. Observed mean annual output was used as a proxy for mean expected output. The derivative of expected price with respect to current price was based on the AR1 model of grain prices (see footnote 16). Estimates of the required supply response parameters were taken from those reported by Bapna, Binswanager, and Quizon.

A quarterly discount rate of .95 was used throughout. In Shirapur, interest rates in the informal sector are high, in many instances approaching 50% (on an annual basis). At the same time, some institutional credit is available at much lower interest rates (although there are sometimes significant transactions costs involved in securing such loans). Finally, short-term interest-free loans among friends and relations are often observed. The discount factor used, which corresponds to an annual interest rate of 23%, was chosen as a median value.

Uncompensated elasticities are presented in table 3. In all instances, profit effects proved large enough to induce positive own-price elasticities in the demand for storable grains in both the lean and harvest seasons. That is, the positive effects of a price change on perceived household wealth, through the enhancement of the value of currently held stocks and expected future net revenue, dominate normal income and substitution effects on consumption. Such positive own-price demand elasticities have long been recognized as a theoretical possibility among semisubsistence households and have been increasingly found in empirical studies which account for profit effects.[17] In the present case, they are attributable to the inclusion of both stocks and the expected value of output into the analysis.

In order to distinguish the relative importance of these two components of the profit effect, the demand elasticities were recalculated, this time omitting stocks of stored commodities from the computations. The results of this exercise (found in table 4) indicate the existence of distinct seasonal differences in the relative magnitude of stock effects and production effects. While there are no dramatic differences in the computed elasticities across seasons, stock effects are particularly strong in the harvest season (when in-

[17] For example, four of the seven empirical studies of semisubsistence households included in Singh, Squire, and Strauss report positive own-price demand elasticities.

Table 2. Income and Compensated Price Elasticities of Demand

Item	Elasticity with Respect to the Price of: X_G	X_2	X_3	Income
Small farms				
X_G	−1.021***	0.192	3.234	0.54***
	(0.38)	(0.29)	(2.30)	(0.08)
X_2	0.534	−1.125***	0.469	0.82***
	(0.53)	(0.41)	(3.20)	(0.12)
X_3	0.578*	0.600**	−4.077**	1.23***
	(0.31)	(0.23)	(1.82)	(0.07)
Medium farms				
X_G	−0.017	0.070	−1.261	0.48***
	(0.43)	(0.37)	(2.86)	(0.10)
X_2	0.278	−0.807**	−0.441	1.03***
	(0.45)	(0.35)	(2.66)	(0.10)
X_3	−0.050	0.428*	−1.348	1.26***
	(0.30)	(0.24)	(1.79)	(0.07)
Large farms				
X_G	−0.370	−0.007	−0.069	0.38***
	(0.41)	(0.40)	(2.64)	(0.06)
X_2	0.652	−1.038**	0.366	0.91***
	(0.61)	(0.46)	(3.61)	(0.11)
X_3	0.485	0.400	−3.078	1.36***
	(0.38)	(0.29)	(2.33)	(0.06)

Note: Commodity groups indicated by the subscripts are: G = stored grains (sorghum and wheat); 2 = nonstorable home-produced foods (vegetables, pulses, other cereals); and 3 = commodities not produced by households (oils, sugars, nonfood). Standard errors are in parentheses. Significance levels of .10, .05, and .01 are denoted by single, double, and triple asterisks, respectively.

Table 3. Uncompensated Own-Price Demand Elasticities and Profit Effects by Season for Stored Grain

Farm Size	Lean Season ϵ_H	Lean Season Profit Effect	Harvest Season ϵ_H	Harvest Season Profit Effect
Small	0.090	1.29	0.159	1.36
Medium	1.104	1.28	1.162	1.34
Large	0.476	0.98	0.590	1.10

Note: Lean season corresponds to the two quarters preceding harvest. Harvest season includes the quarter in which harvest occurs and the following quarter. Profit effects calculated as the difference between the computed demand elasticity and that computed using a conventional Slutsky equation.

ventories are large) and production effects are relatively more important in the lean season. For small farms, ignoring the stock effects reverses the sign of the demand elasticity in both seasons.

The first column in table 4 lists the share of stocks of the stored commodities in household wealth (computed by dividing the value of stocks on hand by the sum of the value of stocks and the value of total consumption). In addition to being large relative to consumption, inventories of grain account for a sizeable proportion of household wealth for all farm-size classes, a fact which explains the empirical importance of stock effects on demand response.

Table 4. Comparison of Demand Elasticities for Stored Grain with and without Stock Effects

Farm Size	Wealth Share of Stocks[a]	Lean Season With Stock Effect	Lean Season No Stock Effect	Harvest Season With Stock Effect	Harvest Season No Stock Effect
Small	.38	0.090	−0.054	0.159	−0.511
Medium	.46	1.104	0.938	1.162	0.488
Large	.52	0.476	0.306	0.590	0.016

[a] Wealth share computed as the value of stocks divided by the sum of the value of stocks and the value of total consumption.

Inventory Demand

Inventory demand equations based on equation (14) were estimated for each farm-size class. In addition to the structural parameters of the theoretical model, sets of household, quarterly, and yearly dummies were included as independent variables in order to account for cross-sectional and intertemporal differences. Because negative inventories (in the form of forward sales, tied credit, and the like) were not observable, a limited dependent variable situation existed. To account for this, a Tobit procedure was used.

The estimated structural parameters of inventory demand are presented in table 5.[18] Only in the case of large farms is there evidence of significant arbitrage motives for holding inventories. This is consistent with the notion that it is only the best-endowed farm households who have the ability to engage in inventory management as a profit-maximizing strategy. Estimates for the food security parameter (g) are highly significant for both the large and medium farm-size classes. For small farms, neither of the parameters representing arbitrage and food security motives were significantly different from zero.

Other results of the inventory demand analysis may be summarized as follows. A large proportion of the household and quarterly dummies were significant, indicating marked seasonal and interhousehold effects. The yearly dummies were in general not significant. Wu-Hausman tests rejected the consistency of the price differential estimator constructured using the ARMA forecasts for the large farm-size class, but not for medium or small farms.

The nonsignificance of the food security parameter for small farm households is somewhat surprising, as it had been thought a priori that food security motives would be greater for households with smaller land holdings. A possible explanation for this is that members of these households were more likely to participate in government-sponsored food-for-work programs. These were plentiful in the village during the period of the analysis and, for the households involved, tended to reduce the necessity of holding stocks for food security purposes.[19]

Table 5. Tobit Estimates of Inventory Demand Parameters

Parameter[a]	Small Farms[b]	Medium Farms[b]	Large Farms[c]
g_o	−754.3***	−1298.0***	−915.1***
	(222.2)	(292.4)	(307.5)
f	−2564.8	−419.5	1395.1***
	(1885.7)	(2132.7)	(456.8)
g	0.99	1.79***	1.48***
	(0.78)	(0.64)	(0.47)

[a] f is the coefficient on the expected price differential (ΔP_t); g is the coefficient on current consumption; and g_o is an intercept. Asymptotic standard errors are in parentheses and significance levels of .10, .05, and .01 are denoted by single, double, and triple asterisks, respectively.
[b] Estimates using ARMA forecast to construct ΔP_t.
[c] IV estimates using the realized price to construct ΔP_t and the ARMA forecast as an instrument.

Short-Run Marketed Surplus Response

The short-run, own-price response of marketed surplus [equation (17)] may be restated in elasticity terms as

$$(19)\quad \mu_i = -(1+g)\cdot\epsilon_{ii}\cdot\frac{X_i}{M_i} + f\cdot\left(1 - b\cdot\frac{dE_tP_{it+1}}{dP_{it}}\right)\cdot\frac{P_i}{M_i}.$$

Here μ_i is the own-price elasticity of marketed surplus of good i, ϵ_{ii} is the uncompensated own-price demand elasticity, and g and f are the parameters of inventory demand associated with food security and arbitrage motives, respectively.

As with demand elasticities, marketed surplus elasticities were evaluated at the seasonal means for the lean and harvest seasons. In the cases where the f and g parameters were not significant, these were set to zero. For ease of interpretation, the absolute value of mean marketed surpluses was used. Thus for households that were net sellers, a positive (negative) marketed surplus indicates that a price increase will lead to greater (less) sales. Similarly, for households that were net purchasers, a positive (negative) elasticity indicates that a price increase will lead to less (more) market purchases.

[18] A .95 discount factor was used in constructing ΔP. To determine the sensitivity of the econometric estimates to the chosen discount factor, several regressions were run with values of b ranging from .90 to 1. The only parameter values affected were g_o and f. The significance level of these parameters remained the same throughout, however, and the implied elasticity of inventory demand with respect to (discounted) expected price was close for all values of b. It was therefore concluded that the chosen discount factor, while somewhat arbitrary, did not significantly modify the implications of the results presented.

[19] The author is indebted to Tom Walker for this insight.

Table 6. Marketed Surplus Elasticities by Season

Farm Size	Lean Season[a] Average Marketed Surplus	μ_t	Harvest Season Average Marketed Surplus	μ_t
Small	−93	−0.20	198	−0.17
Medium	−67	−13.01	287	−3.42
Large	−76	−1.88	225	−1.04

[a] Lean season corresponds to the two quarters preceding harvest. Harvest season includes the quarter in which harvest occurs and the following quarter.

The computed marketed surplus elasticities are presented in table 6. These vary considerably, both seasonally and across farm-size class, and in some cases are extremely large. However, the large values for some of the groups considered are primarily an artifact of the computational method. That is, in cases where the average marketed surplus is small, the computed elasticity tends to be greatly inflated.

Short-run marketed surplus elasticities are negative in both seasons for all farm-size classes. The indication here is that the stock and production effects on consumption that give rise to positive own-price demand elasticities outweigh the positive effect of the diminished intertemporal arbitrage opportunities implied by a narrowing of the gap between current and expected prices. Thus, in the short-run households appear to respond to price rises by increasing consumption at the expense of market sales.

Long-Run Elasticities

Table 7 presents two sets of long-run demand and marketed surplus elasticities, one set computed using the methods developed above and one set computed by the methods described in Strauss (1986). To facilitate comparison, all elasticities were calculated using annual averages for production and consumption and the Bapna, Binswanger, and Quizon supply response parameters. Steady-state inventory holdings were taken to be quarterly means over the entire year, i.e., average stocks held by a household in any given period. Finally, in computing the production effects on demand, dE_tP_{1t}/dP_{1t} was set equal to 1 on the grounds that steady-state prices would be expected to follow a random walk.

Table 7. Long-Run Own-Price Demand and Marketed Surplus Elasticities for Stored Grain

Farm Size	Strauss' Method ϵ_{ii}[a]	μ_i[a]	New Method ϵ_{ii}	μ_i
Small	−0.977	7.59	−0.778	6.80
Medium	0.043	2.54	0.236	2.02
Large	−0.344	6.40	−0.180	5.56

[a] ϵ_{ii} is uncompensated demand elasticity; μ_i is marketed surplus elasticity.

Not surprisingly, long-run own-price elasticities computed using the methods developed here are more elastic than their short-run counterparts. Importantly, all long-run marketed surplus elasticities are positive, indicating the importance of output response in determining long-run marketed supply. Additionally, long-run demand elasticities are negative for two of the three groups of households. Only for households of the medium farm-size class are wealth effects large enough to dominate normal income and substitution effects.

While all elasticities computed using Strauss' method are of the same sign as those computed using the new method, the magnitudes differ. Strauss' method also yields positive own-price demand response for medium farms, an indication of the strength of production effects for households of this farm-size class. In all cases, however, demand response computed using Strauss's method is considerably more elastic than that computed using the new method, indicating that stock effects are also empirically important.

Marketed surplus elasticities calculated using Strauss's method are 11% to 25% larger than those computed using the new method. That the estimates using Strauss's method are uniformly larger than those computed using the new method is true for much the same reason that the demand elasticities differed uniformly. That is, the earlier method systematically understates wealth effects on consumption by failing to recognize the role of stocks and therefore tends to overstate the elasticity of demand (and hence marketed surplus).

Concluding Comments

A model of semisubsistence agriculture explicitly accounting for the ability of farm households to hold inventories of staple foods has been developed in this paper. The theoretical and em-

pirical analyses sought to determine the nature of demand and marketed surplus response both within the cropping cycle (when output is fixed) and in the long run (when it can vary).

Long-run marketed surplus response was found to be positive and quite elastic for all farm-size classes considered. Using the same data and parameter estimates, the method employed in earlier work to compute marketed surplus elasticities was found to overstate marketed surplus elasticities by 11% to 25%. This difference occurs because the earlier method failed to incorporate the wealth effect on consumption of changes in the value of household stocks resulting from price changes.

Short-run marketed surplus elasticities were negative in all cases. In conjunction with the finding of positive short-run demand elasticities, this result indicates that within the cropping cycle households respond to price rises by increasing consumption at the expense of market sales. Determining whether this result is due to the methodological refinements developed here rather than to peculiarities of the data used will require additional research. It would be of particular interest to conduct such research in areas where stocks account for a large share of total household wealth because the findings here suggest that negative marketed surplus response is most likely to occur in these cases.

The important methodological conclusion is that the value of currently held stocks should be included in analyses of commodity demand and marketed surplus response in the context of semisubsistence agriculture. This is true whether or not inventories are responsive to price changes because stock effects on consumption depend on the absolute level of inventory holdings. These stock effects were shown to have potentially large impacts on the own-price response of consumption demand (and thus marketed surplus) for stored commodities.

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Pass-Through of Exchange Rates and Tariffs in Brazil–U.S. Tobacco Trade

Gregory K. Pompelli and Daniel H. Pick

This paper examines the extent to which exchange rate and tariff changes are passed through in U.S. import prices of unmanufactured tobacco from Brazil. The model used considers the possibility of market imperfections in international trade and the potential effects of strategic trade policies. The results indicate that agricultural prices may not be as flexible as commonly thought. Furthermore, exchange rate and tariff changes are not fully passed through to U.S. tobacco import prices, which indicates that firms selling Brazilian tobacco may use trade strategies to maintain or even increase their trade shares in the U.S. tobacco market.

Key words: Brazil, international trade, pass-through effects, strategic trade policy, tobacco.

Historically, U.S. tobacco producers have maintained significant product quality differences which have helped insulate them from international competition. However, these quality differences have diminished as the quality of foreign tobacco has improved (GAO). Certainly, the growing share of imported tobacco in the U.S. domestic market is partial evidence that quality no longer acts as a sufficient barrier. As the following analysis of Brazilian tobacco imports highlights, strategic trade policy actions have become important factors that will potentially exert even greater influence on U.S. tobacco producers in the future.

Imports of Brazilian unmanufactured tobacco by cigarette makers in the United States have become an important part of the market. Between 1975 and 1985, the Brazilian share of the U.S. domestic unmanufactured tobacco market increased from 3% to 6%. Although this may not appear to represent a substantial share of the market, it reflects significant changes in the U.S. market for unmanufactured tobacco. At present, imports of Brazilian tobacco represent almost 20% of the tobacco imported into the United States.

In addition to, but typically divorced from, concerns voiced by domestic tobacco producers, these changes have heightened interest in the influence of government intervention in trade and the use of strategic trade policies. While much of the attention has centered on trade barriers, there has also been an increased interest in the use of strategic trade policies and the relationship between exchange rate and tariff changes and prices of imported goods (Baron, Jabara and Schwartz, Richardson). Since the mid-1970s, the scope of interest has grown to include the effects of trade policies in situations where nations and/or firms possess market power in international markets or where markets are not perfectly competitive (Eaton and Grossman, Feenstra, Venables).

This paper examines the extent to which exchange rate and tariff changes are passed through in U.S. import prices of unmanufactured tobacco from Brazil. A number of studies, including Isard, Richardson, Dunn, Jabara and Schwartz, and more recently Feenstra, have found that the "law of one price" has failed to hold for a fairly wide range of traded goods. That is, exchange rate changes are less than fully passed through in import prices. Thus, treatment of agricultural commodities as price-flex goods is

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questioned, especially in markets where trade barriers and/or strategic trade policies are implemented.

Literature

Various studies have addressed imperfect competition and the use of strategic trade policy. At the same time, a separate literature pertaining to transmission effects of exchange rates to domestic import prices has also been developed. Dunn analyzed the pass-through effect of exchange rates on import prices in the Canadian markets under the hypothesis of imperfect competition. Under this hypothesis firms that wish to maintain stable prices in foreign markets must exhibit market power with a system of variable price discrimination. Dunn's results for Canadian imports support this hypothesis. Support for Dunn's hypothesis of discriminatory pricing behavior was also found by Giovannini, who studied Japanese and U.S. markets.

A different approach to exchange rate pass through was introduced by Goldstein, who studied the so called "ratchet" hypothesis. This concept states that exchange rate changes have inflationary bias since world prices are inflexible downward. His results show some support for the hypothesis of discriminatory pricing behavior in certain nations.

Other studies that have examined the effect of exchange rates on import prices include Kreinin, Dornbusch, and Woo. While Kreinin concentrated on pass-through effects, the Dornbusch analysis emphasized the importance of market structure on the transmission of exchange rate changes to prices. Woo found that import prices fail to fall by the full amount of the depreciation of the foreign currency. His findings are consistent with the price discrimination model where foreign firms are able to discriminate by charging higher prices in countries with high costs and lower prices in countries with lower costs.

Jabara and Schwartz investigated the asymmetric effects of exchange rate changes on domestic prices of agricultural commodities in Japan. Their results indicate that commodity prices in Japan exhibit "stickiness," which supports the "ratchet" hypothesis proposed by Goldstein.

The issue of tariff and exchange rate pass through in domestic prices has also been explored by Feenstra, who applied his model to the case of small truck and motorcycle imports from Japan. His results suggest a symmetric pass through of exchange rates and tariffs in domestic prices. Feenstra's results are based on products that are subject to ad valorem tariffs. As a result, he was able to test whether tariff and exchange rate pass-through effects were symmetric.

Note, however, that Feenstra's symmetric pass-through hypothesis pertains to the similarity of the pass-through effects for tariffs and exchange rates. The Jabara and Schwartz, and Goldstein "ratchet" symmetry hypotheses are concerned with similarity of pass-through effects when exchange rates are falling and rising. This paper does not examine the "ratchet" symmetry case because, on an annual basis, the cruzeiro/dollar exchange rate only moved in one direction during the period used. Instead, symmetry between tariff and exchange rate pass-through effects may be examined by comparing the coefficients in the estimation results.

Methodology

Following Feenstra, the model used in this analysis assumes that a foreign or multinational firm (in this study a firm operating in Brazil) faces an import demand function $X(Pm, Pd, Ps, Y)$, where X denotes quantity; Pm and Pd denote the import and domestic good prices in the domestic currency of the importing nation; Ps is the price of substitutes denominated in the domestic currency of the importing nation; and Y denotes domestic expenditure or absorption of the importing nation. In this study, tobacco firms in Brazil face a U.S. demand function for their tobacco which is a function of the price of Brazilian tobacco (Pm), the price of United States tobacco (Pd), the price of substitute tobacco (Ps), and income or domestic expenditure (Y). A tobacco firm in Brazil (foreign firm) faces a cost function $C(X, W)$, where W denotes a vector of aggregate foreign input prices. Thus the profit-maximization problem facing a firm in an imperfectly competitive industry can be derived by maximizing profit with respect to the choice variable, Pm, as follows:

$$(1) \quad \text{Max } [q(Pm - t)X(Pm, Pd, Ps, Y) - C(X, W)],$$

where q is the cruzeiro/dollar exchange rate and t is a specific or unit tariff. While other studies suggest that currency invoicing decisions are important (Baron, McKinnon), it is assumed under the above specification that the foreign firm receives payments in the domestic currency

($US).[1] Bilson, and Hooper and Kohlhagen provide a more detailed discussion of this assumption.

Given that the cost function is homogenous of degree one, equation (1) can be written as follows:

$$(2) \quad \text{Max } [q(Pm - t)X(Pm, Pd, Ps, Y) - f(X)W)],$$

or equivalently,

$$(2a) \quad q\text{Max } [(Pm - t)X(Pm, Pd, Ps, Y) - f(X)W/q].$$

The first-order condition for equation (2a) can be written as

$$(3) \quad f'(X)(W/q) + t = Pm[1 - 1/\eta] \equiv R(Pm, Pd, Ps, Y),$$

where $\eta = (-\partial X/\partial Pm)(Pm/X)$, and $R(Pm, Pd, Ps, Y)$ represents marginal revenue.

The first-order condition of this specification implies that marginal revenue is equal to marginal cost plus the unit tariff. Assuming that $[f''X_{pm}(W/q) - R_{pm} \neq 0$, then equation (3) can be inverted into a pricing equation. Solving the first-order condition for the producer price $P\tilde{m} = (Pm - t)$, equation (4) may be used to represent the general functional form for the pricing equation:

$$(4) \quad P\tilde{m} = g[W/q, Pd, Ps, Y, t].$$

Equation (4) is homogenous of degree one and using a loglinear specification, it can be written as follows:

$$(5) \quad \ln P\tilde{m} = \alpha + \beta_1 \ln(W/q) + \beta_2 \ln(Pd) + \beta_3 \ln(Y) + \beta_4 \ln(t) + \beta_5 \ln(Ps) + \ln(e_t).$$

This model assumes that all exchange rate adjustments occur in the current period because annual data are used in the analysis.

As shown in Feenstra, β_1 is expected to be positive and may be greater than one, though the standard case would be that factor cost/exchange rate changes are positive but less than fully passed through. The domestic price coefficient, β_2, is expected to be positive but not greater than one. Again, the standard case would be that domestic price changes are positive but less than fully passed through. However, the pass-through effect could be negative in the case where exporters' marginal costs decline as imports rise. The income coefficient, β_3, theoretically may be positive or negative, as Deardorff and Stern note. The tariff pass-through coefficient, β_4, is expected to be positive and follow the exchange rate pass-through effect; yet, it is not restricted to equal the exchange rate effect. Finally, the substitute price coefficient, β_5, is expected to be positive.

For estimation, the error term (e_t) is assumed to be lognormally distributed with an expected value of zero. Normally, the import tobacco price equation could be tested for homogeneity of degree one by testing if $\beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5 = 1$. However, the validity of the test was questioned due to multicollinearity problems that are discussed in the following section.

Data

All the data used in this study are annual data covering the period 1964 to 1983. The annual U.S. import prices of tobacco from Brazil (Pm), and Italy (Ps) were calculated using the quantity and value figures from annual issues of the U.S. Bureau of the Census *U.S. Imports for Consumption and General Imports Report FT246*. The U.S. import price for Italian tobacco represents the substitute price (Ps).[2] All prices are calculated exclusive of the specific tariff rate. The Brazilian exchange rate (cruzeiros per U.S. dollar) (q) and producer price index (W) data were obtained in issues of the *International Financial Statistics Yearbook* (IMF). The domestic price (Pd) data for tobacco were obtained from the United States Department of Agriculture issues of the annual *Tobacco Situation and Outlook Reports*. Retail expenditure (Y) data for tobacco products were obtained in *Business Statistics: 1986* (USDC 1987).

The United States tobacco tariff rates (t) were collected from the U.S. International Trade

[1] This assumption is particularly appropriate for the case of tobacco because international prices are denominated in U.S. dollars, and trade occurs in U.S. dollars as well. The pass-through effects of exchange rate changes in such cases where prices and receipts are denominated in the same currency can be viewed as an outcome of a trade strategy. For example, if the U.S. dollar appreciates in value relative to the Brazilian cruzeiro, then firms operating in Brazil will experience a windfall gain in their revenues (once converted into cruzeiros). These firms might then decide to try to gain market share in international markets by lowering the U.S. dollar price of the tobacco they export, while leaving their revenues denominated in cruzieros unchanged.

[2] The U.S. import price of Italian tobacco is used as the representative substitute price because its quality was relatively close to Brazilian tobacco and it maintained a consistent presence in the U.S. market.

Commission. Tariff rates for Brazilian tobacco imports were adjusted to account for the import classification changes that occurred in the early 1980s. Prior to 1980 roughly 75% to 100% Brazilian imports were classified as scrap tobacco. After 1980, Brazilian tobacco was classified as manufactured/unmanufactured tobacco. Finally, in 1983, Brazilian tobacco was reclassified as stemmed leaf. The stemmed leaf tariff, beginning in 1979 at 45¢ per pound, was reduced by 3¢ per pound per year with a tariff rate goal of 23¢ per pound. Currently, most of Brazil's tobacco is imported into the United States at stemmed rate. The combination of the reclassifications and the declining tariff schedule for stemmed tobacco has caused the effective tariff on Brazilian import to fluctuate during the period of the analysis.

In general, most of the independent variables in the data did not exhibit high simple correlations. However, multicollinearity problems in estimation were a primary concern because of the correlation coefficient of 0.98 for the domestic price (*Pd*) and the domestic absorption (*Y*) variable; therefore, neither variable was dropped from estimation. As a result, the only property claimed for the resulting estimates is that they are at best unbiased. Multicollinearity problems may have been mitigated somewhat by imposing the restriction that equation (5) is homogenous of degree one (Judge et al., chap. 22). However, no efficiency gains are claimed for the resulting estimates.

Table 1. Tobacco Import Price Equation Results

Variable	Parameter Estimates
Intercept	−1.360
	(−1.13)[a]
Pass-through (W/q)	0.145
	(0.30)
Domestic (Pd) price	−0.985
	(−1.14)
Domestic (Y) absorption	1.082*[b]
	(1.88)
Tariff (t)	0.549*
	(2.19)
Italian (Ps) price	0.208*
	(1.95)
Durbin-Watson statistic	1.27
Observations	20
R^2	0.79
Adjusted R^2	0.74

[a] Numbers in parentheses are t-values.
[b] Significant at the .95 level.

Results

Table 1 contains the estimates for the restricted tobacco import price equation. The Durbin-Watson statistic at 1.27 falls into the inconclusive range of first-order autoregression. However, residual plots did not indicate any problems that justified correction for a potential autoregressive error term. In addition, the limited number of observations and the presence of multicollinearity further reduced any potential gains from correction. As indicated by the R^2 value of .79, the overall fit of the restricted tobacco import price equation is good.

The exchange rate pass-through coefficient at 0.145 is insignificant. It appears that Brazilian prices of unmanufactured tobacco imported into the United States, at best, only partially reflect changes in exchange rates or factor prices. This may indicate that Brazilian firms have used exchange rate changes to maintain, or even increase, their share of the U.S. tobacco market. Given that most of the United States imports from Brazil are sold by U.S. subsidiaries or multinational tobacco corporations, this may also reflect an attempt on their part to substitute cheaper Brazilian tobacco for more expensive U.S. tobacco. The growth of Brazilian import share in the U.S. tobacco market from less than 10% in 1977 to roughly 20% in 1986 supports this result. However, time trends were unable to capture quality changes in earlier estimations and were dropped from the analysis.

The statistically significant tariff pass-through effect of 0.549 indicates that the U.S. tariffs on unmanufactured tobacco are only partially passed through to import prices. As Feenstra, and Brander and Spencer note, a tariff pass-through effect that is less than one indicates that the importing country achieves terms of trade gains. Thus, there is some evidence in favor of import protection for U.S. tobacco growers through the use of tariffs.

The influence of the domestic producer price on the import price of Brazilian tobacco is not statistically significant. At −0.985, it indicates that U.S. domestic prices have little or no impact on the import price of Brazilian tobacco. This may be the result of the U.S. tobacco program, which maintained domestic tobacco prices above world prices during that period.

The domestic tobacco absorption coefficient at 1.082 is statistically significant at the .95 level and indicates that changes in consumption of to-

bacco in the domestic market are fully reflected in Brazilian import prices. The positive value yields some information about the general relationship between domestic absorption and tobacco import prices. As one reviewer noted, this may represent a "demand shifter to represent the effects of the business cycle. . . ." However, as Deardorff and Stern observe considerable debate surrounds the relationship between import prices and domestic expenditures.

The substitute tobacco import price coefficient (Ps), represented by the Italian import tobacco price, at 0.208 is statistically significant. Thus, Brazilian import tobacco prices are somewhat sensitive to price changes of substitutes. The lack of greater cross-price influences may be attributable to the degree of substitutability between the tobaccos from each of these regions.

While there are no other exchange rate and tariff pass-through estimates available for tobacco that can be used to compare with these results, the Jabara and Schwartz estimates for several other agricultural commodities provide some reference. They estimated the exchange rate pass-through effects to equal −.45 for beef, .31 for corn, and .25 for soybeans. However, comparisons are limited because Jabara and Schwartz estimated a quarterly model for the period from 1974 to 1984, and they focused on trade with Japan. Nonetheless, their findings and the results from this study indicate that agricultural prices may not be as flexible as commonly assumed.

Conclusion

This paper develops a model for assessing the pass-through effects of exchange rates and per unit tariffs in the case when the market is not purely competitive. The results provide interesting insights into the transmission of exchange rate and tariff changes to tobacco import prices. Most notably, exchange rate changes do not appear to be passed through in import prices, which would tend to indicate an attempt to increase the Brazilian share in the U.S. tobacco market. The .549 tariff pass through, however, indicates that part of the tariff is being borne by Brazilian firms.

In addition, the exchange rate pass through result corresponds with the findings in other pass-through studies that the treatment of agricultural goods as price flexible, needs to be reconsidered. This is especially true where firms or industries operate in imperfect international agricultural markets or where strategic trade policies aimed at trade promotion are used.

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A Revised Test of the Law of One Price Using Rational Price Expectations

Barry K. Goodwin, Thomas J. Grennes, and Michael K. Wohlgenant

The law of one price (LOP) is an important ingredient in theories of international trade. Typical analyses of the LOP assume that parity should hold contemporaneously. This assumption overlooks temporal elements of trade. Recognizing this fact, we expect parity to hold for expected prices. Two empirical procedures are utilized to consider the LOP in international markets for U.S. agricultural commodities. The first utilizes econometric procedures to test an expectations augmented version of the LOP. A second approach uses nonparametric procedures to provide an alternative consideration of expectations. In each case, results provide support for a rational expectations view of the LOP.

Key words: generalized method of moments, international trade, law of one price, rational expectations.

The law of one price (LOP) is an essential ingredient in theories of international trade and exchange rate determination. As Officer (1986) notes, without this principle the traditional "pure" theory of international trade would not exist. In short, the LOP maintains that foreign and domestic prices of a commodity will be equal when both are expressed in the same currency and net of transportation costs. This equality will be established and maintained by the profit-seeking actions of international commodity traders and arbitragers.

Empirical literature on the LOP is extensive. The strand of literature dealing with aggregate price indexes is usually called absolute purchasing power parity. The large literature on disaggregate products is summarized by Officer (1989), and most of the results are unfavorable to the LOP. "Of 40 tests, 28 reject the LOP, eight have mixed findings, and only four unambiguously cannot reject the LOP" (Officer 1989, p. 3).

The law of one price in international agricultural markets has received limited attention. Jabara and Schwartz find that the behavior of agricultural prices between the United States and Japan is not as flexible as is commonly perceived. Smith found weak support for the LOP using annual data for wheat, corn, and rice. Ardeni indicates that the LOP fails as a long-run relationship in several important agricultural markets, and that deviations from the LOP are permanent.

An important shortcoming of these studies is the assumption that parity should hold contemporaneously.[1] This assumption overlooks the fact that international commodity arbitrage and trade occur over time as well as across spatially separated markets. Thus, parity should not be expected for contemporaneous spot prices unless arbitragers have perfect foresight or unless prices are constant. Rather, international commodity arbitragers likely act upon the expected sale prices for when their goods are delivered. Thus, we would instead expect parity to hold for expected prices.

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[1] An important exception is Magee, who recognized that ignoring delivery lags could result in spurious deviations from purchasing power parity.

The objective of this paper is to incorporate expectations into an empirical investigation of the law of one price. The application is to international markets for relatively homogenous U.S. agricultural commodities. The empirical investigation proceeds along two distinct lines. The first makes use of the generalized method of moments (GMM) procedures set forth by Hansen, and Hansen and Singleton (1982, 1983).[2] A second approach employs nonparametric tests of parity conditions (Frenkel and Levich). These results are utilized to provide an alternative consideration of the role of delivery lags in international price linkages which may overcome potential limitations associated with regression-type tests of the LOP.

The paper is organized as follows. The next section develops a model of the law of one price in international commodity markets. The model then is applied econometrically to international markets for several important U.S. agricultural commodities, and the nonparametric approach is utilized as well. The final section reviews the results and offers some concluding remarks.

A Model of the Law of One Price

The law of one price is tested using prices of primary commodities for three basic reasons. First, a good's price may reflect the presence and quality of certain utility bearing attributes (Rosen). In this case, goods with different attributes are expected to have different values and thus different prices. A primary commodity is most likely to possess identical attributes regardless of origin or destination. Second, aggregated data experience the problems associated with indexes and aggregation measurement errors. Tests which use aggregate data may fail in part because of aggregation and index construction errors. Finally, it is likely that exchange rates will be endogenous to the system used for testing when highly aggregated price data are used. The existence of such endogeneity explicitly biases the results of standard regression tests. Using primary commodity prices substantially reduces the likelihood of this problem.

Most LOP tests utilize a model similar to Richardson's:

$$P_{it} = \alpha_0 P_{it}^{*\alpha 1} \pi_{12t}^{\alpha 2} T_{it}^{\alpha 3} R_{it}^{\alpha 4}, \tag{1}$$

where P_{it} is country one's price of commodity i in time t, P_{it}^* is country two's price of commodity i in time t, π_{12t} is the rate of exchange for currency two in terms of currency one, T_{it} is transfer and transactions costs of trade in commodity i between countries one and two, R_{it} is the residual reasons for price differences between countries one and two, and α_0, α_1, α_2, α_3, and α_4 are parameters. Strict adherence to the law of one price requires that the domestic price of a good, once adjusted for exchange rates, transfer costs, and any differences in quality, will be equal to the foreign price of the good. If a disparity between these prices is detected by international commodity arbitragers, they will buy the good in the lower-priced market and sell it in the higher-priced market until prices are equalized. Thus, for a basic homogenous commodity, adherence to the LOP requires that

$$\alpha_0 = \alpha_1 = \alpha_2 = \alpha_3 = 1, \text{ and } \alpha_4 = 0. \tag{2}$$

Thus, equation (1) becomes a statement of the law of one price.

Several weaknesses are inherent in the standard approach to testing the law of one price. First, independent information about transportation costs is rarely available. Thus, transport costs usually are assumed constant or proportional to commodity prices over the period of study. Under these specifications, T_{it} could be removed as a variable in the equation and transport costs could be represented in an intercept term. Such an approach is implicitly assumed by Jabara and Schwartz and by Ardeni. However, these assumptions are questionable in light of the potential volatility of transport and other transactions costs. Binkley and Harrer show that transport costs can be highly variable and may be influenced by several factors including ship sizes and trade volumes. Goodwin, Grennes, and Wohlgenant show that deviations from parity may be correlated with transport and interest costs.

The empirical analyses conducted in this study utilize actual freight rates for wheat to represent transactions costs associated with trade in seventeen oilseed and grain markets. Moreover, because homogenous primary commodities are the focus of this analysis, there are no residual reasons for price differences. Thus, R_{it} is omitted and treated as an unobservable random disturbance.

Another shortcoming of the standard approach to testing price parity is that regression tests of the form given by equation (1) require that one of the commodity prices is exogenous.

[2] This method has been applied by Antle to a measurement of risk.

This may be incorrect for an individual commodity. While exchange rates often are exogenous to a particular commodity price, prices in two trading countries may be simultaneously determined regardless of the relative sizes of the countries (Protopapadakis and Stoll). Information may be shared across markets and agents may operate in multiple markets. Such simultaneity biases the resulting parameter estimates and confounds statistical inference. Accordingly, the approach followed in this study is designed to overcome this weakness by utilizing instrumental variables.

A major shortcoming of the standard LOP tests is the use of contemporaneous domestic and foreign prices in the empirical analysis. This analysis will instead utilize a simple expectations model. Each market is assumed to specialize in either importing or exporting the commodity in question, consistent with the concept of comparative advantage. In particular, the home country is an exporter and the foreign country is an importer. The consideration of expectations is limited to one side of the exchange so that exporters respond to their expectations of prices at the time of delivery in the foreign market. In turn, this response influences the price of the commodity in the domestic market. The result is parity between current domestic prices and expected future foreign prices. Comparisons in which both markets are net importers or net exporters are also possible. However, these comparisons are less relevant for U.S. agricultural commodities.

It is instructive to consider a simple intertemporal model which yields the LOP conditions as a result of arbitrage and trade profit maximization.[3] The arbitrager's problem is to maximize expected profits from trade over time, given a stream of exogenous commodity prices. Consider a representative agent engaged in arbitrage and trade for a single commodity in two spatially separated markets with no storage opportunities. The agent maximizes expected profits by choosing quantities of a commodity to sell in the domestic market in time t and to export to the foreign market for sale upon delivery in time $t + j$. The delivery lag of j periods reflects the physical transfer of commodities in the trade process. The agent faces transportation and nontransportation costs associated with trade and arbitrage activities. The latter costs include set-up costs, acquisition expenses, and the costs of inputs into the arbitrage and trade process. This cost component is assumed to vary directly with the total amount of the commodity placed into arbitrage and trade activities (in both the domestic and foreign markets).

Under these conditions, the agent's problem is to maximize expected profits, given by $E_t V(q_t, q_t^*)$, where

$$(3) \quad V(q_t, q_t^*) = \sum_{t=0}^{\infty} \{\delta^t [p_t q_t + \delta^j \pi_{t+j} p_{t+j}^* q_t^* - C(Q_t) - \tau_t q_t^*]\},$$

q_t is the quantity of the commodity sold in the domestic market in time t, q_t^* is the quantity of the commodity exported to the foreign market in time t, p_t is the commodity price in the domestic market in time t, p_{t+j}^* is the commodity price in the foreign market in time $t + j$, π_{t+j} is the rate of currency exchange in time $t + j$, $C(\ )$ is the commodity arbitrage cost function, Q_t is the total quantity of commodity engaged in trade and arbitrage activities in time $t (Q_t = q_t + q_t^*)$, τ_t is the per-unit transactions charges in time t, and δ is a discount factor $(0 < \delta \leq 1)$.

Note that $E_t(x) = E(x | \Omega_t)$, where E is the mathematical expectations operator conditional on the information set available at time t, Ω_t. We assume that $\Omega_t \supset \{p_t, p_t^*, x_t, \Omega_{t-1}\}$ for all t, where x_t is a vector of random variables exogenous to the agent.

The first-order conditions for profit maximization for all $k \geq 0$ are given by

$$(4) \quad E_{t+k}\{\delta^k [p_{t+k} + C'(Q_{t+k})]\} = 0,$$

$$(5) \quad E_{t+k}\{\delta^k [\delta^j \pi_{t+j+k} p_{t+j+k}^* - C'(Q_{t+k}) - \tau_{t+k}]\} = 0.$$

If these conditions adequately represent aggregate profit-maximizing behavior, they can be arranged at $k = 0$ to yield:

$$(6) \quad E_t\{p_t - \delta^j \pi_{t+j} p_{t+j}^* + \tau_t\} = 0,$$

which is equivalent to

$$(7) \quad p_t - \beta_0 E_t\{\pi_{t+j} p_{t+j}^*\} + \tau_t = 0,$$

[3] The behavioral model which follows is an abstract representation of actual grain trading practices. In reality, international grain trade is highly organized and shipments may flow through several agents before reaching end-users. A large percentage (85%–90%) of U.S. grain exports are handled by five companies: Cargill, Continental, Bunge and Born, Louis Dreyfus, and Andre Garnac (Davies). These companies conduct marketing and arbitrage activities as they arrange the exchange of grain and oilseed commodities between domestic producers and foreign end-users. Such activities are often carried out under contract. However, despite our simplified representation of the trade and arbitrage process, the fundamental result that trade profit maximization ensures the equalization of expected marginal returns remains valid.

where $\beta_0 = \delta^j$. Equation (7) is a formal statement of the law of one price.

Rational expectations specifies that the future price equals the agent's subjective price expectation plus a random error term. In turn, this implies that the actual future price will be correlated with the contemporaneous disturbance term. Thus, least squares estimators will be biased and inconsistent. The generalized method of moments (GMM) estimator is used to purge this price variable of its correlation with the disturbance term and to obtain consistent and asymptotically efficient estimates of the parameters of the expectations-augmented model of the LOP. The GMM estimator exploits the property that rational expectations are conditional expectations of sample moments. It minimizes a sample error objective function by applying instrumental variables estimation techniques directly to orthogonality conditions which are implied by the first-order conditions (4) and (5). The resulting parameter estimates provide a rational expectations interpretation of the law of one price which can be compared to the standard formulations of the LOP which utilize *ex post* contemporaneous prices.[4]

An Application to U.S. Agricultural Commodity Prices

This section applies the standard and expectations-augmented models of the law of one price to internationally traded agricultural commodities. If standard tests of the LOP misrepresent the intertemporal elements of commodity trade and arbitrage, tests explicitly recognizing the role of expectations should find stronger empirical support for the concept of international price parity. The empirical applications are to international markets for U.S. origin wheats (see table 1 for the six classes of U.S. wheat), oilseed products, corn, and grain sorghum. These markets are of special interest because of their prominent role in U.S. agricultural trade. In 1987, the grain and oilseed markets accounted for over 59% of the total value of U.S. agricultural exports (U.S. Department of Agriculture 1988).

The data represent monthly market observations for internationally traded primary commodities.[5] Statistical price data for internationally traded commodities are available from various sources. The oilseed product prices were collected from the Foreign Agriculture Service's *Oilseeds and Products*. These prices were quoted monthly at various U.S. interior and export market locations and at Rotterdam. Wheat prices were collected for several varieties of wheat from the International Wheat Council's *World Wheat Statistics*. These prices were quoted monthly at various U.S. export markets and at Japanese and Rotterdam import markets. The corn and grain sorghum prices were taken from the Foreign Agriculture Service's *Grain Market Outlook*. These prices were quoted monthly at various U.S. markets and at Rotterdam. The Rotterdam market is a major port of entry and transshipment point for U.S. agricultural products moving into the European market.

Border prices are more appropriate for the LOP than internal prices because they better represent arbitrage opportunities. Internal prices may differ because of tariffs, domestic transport costs, processing costs, and sales taxes, without providing any opportunity for profitable arbitrage. For example, Officer (1989, p. 17) found that the largest deviations from the LOP among ten categories of food, beverages, and tobacco occurred for alcoholic beverages and tobacco. He attributed the large deviations to special indirect taxes and monopoly distribution (Officer 1989, p. 17). The use of border prices avoids this problem.

Characteristics of the data are summarized in table 1. However, two important issues should be addressed at this point. First, several of the price series had a small number of missing observations. Because of the importance of the time series structure of the data, deletion of observations was considered too strong a step. Thus, portions of the data that were complete or nearly complete were isolated, and univariate time-series models were used to forecast the missing observations. In no case were more than two consecutive missing observations or more than five missing data points overall estimated in this fashion. The number of missing observations for each series is included in table 1. Of course, such a procedure may introduce biases and inconsistencies in the estimation and subsequent statistical inferences.

A second issue is that international trade in

[4] A more detailed discussion of the econometric procedures and alternative applications of the LOP models are contained in Goodwin. A detailed discussion of the GMM procedures applied to the expectations augmented model of the LOP is available from the authors upon request.

[5] The homogenous product categories are based on grade and variety attributes whenever possible, and are narrower than most found in the literature.

Table 1. Description of Price Variables

Commodity	Description	n	n-miss	period
U.S. soybeans	U.S. farm-level average	72	0	1/80–12/85
Rotterdam soybeans	No. 2 U.S. origin, cif	72	0	1/80–12/85
U.S. sunflowerseed	U.S. farm-level average	72	1	1/80–12/85
Rotterdam sunflowerseed	U.S./Canadian origin, cif	72	1	1/80–12/85
U.S. soybean meal	Decatur, 44% protein, FOB	72	0	1/80–12/85
Rotterdam soybean meal	U.S. origin, 44% protein, cif	72	0	1/80–12/85
U.S. cottonseed meal	Memphis, 41% protein, FOB	72	0	1/80–12/85
Rotterdam cottonseed meal	Denmark, 38% protein, cif	72	1	1/80–12/85
U.S. soybean oil	Decatur, crude average	72	0	1/80–12/85
Rotterdam soybean oil	Dutch ex-mill, FOB	72	0	1/80–12/85
U.S. cottonseed oil	Valley Points, FOB	72	1	1/80–12/85
Rotterdam cottonseed oil	U.S. origin, cif	72	2	1/80–12/85
U.S. sunflowerseed oil	Minneapolis, FOB	72	0	1/80–12/85
Rotterdam sunflowerseed oil	Rotterdam ex-mill	72	0	1/80–12/85
U.S. peanut oil	Southeastern mills, FOB	72	0	1/80–12/85
Rotterdam peanut oil	Rotterdam, any origin, cif	72	0	1/80–12/85
U.S. sunflowerseed meal	Minneapolis 41% protein, FOB	72	0	1/80–12/85
Rotterdam sunflowerseed meal	Argentina/Urguay origin 38% protein, cif	72	0	1/80–12/85
U.S. Wheat 1	No. 2 Hard Winter 13%, Gulf FOB	72	0	11/75–10/81
Japan Wheat 1	U.S. origin No. 2 Hard Winter 13%, cif	72	5	11/75–10/81
U.S. Wheat 2	No. 2 Western White 13%, Pacific FOB	79	0	7/75–1/82
Japan Wheat 2	U.S. No. 2 Western White 13%, cif	79	2	7/75–1/82
U.S. Wheat 3	No. 2 Dark Northern Spring 14%, Gulf FOB	79	0	7/75–1/82
Japan Wheat 3	U.S. No. 2 Dark North Spring 14%, cif	79	5	7/75–1/82
U.S. Wheat 4	No. 2 Dark North Spring 14%, Pacific FOB	79	0	7/75–1/82
Japan Wheat 4	U.S. No. 2 Dark North Spring 14%, cif	79	5	7/75–1/82
U.S. Wheat 5	No. 2 Dark North Spring 14%, Gulf FOB	128	0	7/75–12/85
Rotterdam Wheat 5	U.S. No. 2 Dark North Spring 14%, cif	128	0	7/75–12/85
U.S. Wheat 6	No. 2 Soft Red Winter, Atlantic FOB	79	0	7/79–12/85
Rotterdam wheat 6	U.S. No. 2 Soft Red Winter, cif	79	0	7/79–12/85
U.S. corn	No. 3 Yellow, Gulf FOB	92	0	1/80–12/85
Rotterdam corn	U.S. average, No. 3 Yellow, cif	92	0	1/80–12/85
U.S. grain sorghum	No. 2 Yellow, Kansas City	114	0	7/73–12/82
Rotterdam grain sorghum	U.S. origin No. 2 Yellow, cif	114	0	7/73–12/82

U.S. agricultural products is customarily invoiced in dollars in both domestic and foreign markets (Hathaway, p. 14). Thus, prices of U.S. agricultural products in foreign markets are often quoted in dollars, as occurs in this analysis. Because trade is conducted solely in dollars, the implied rate of currency exchange is everywhere identically equal to one. The elimination of a direct consideration of exchange rates focuses attention upon the real issue of arbitrage and price behavior. Attempts at separating price and exchange rate effects in empirical tests of the law of one price have been criticized as being too restrictive and without justification by Crouhy-Veyrac, Crouhy, and Melitz.

The empirical implementation of the expectations augmented version of the law of one price requires a fixed delivery lag length. Because of the wide range of commodities and markets under consideration, actual delivery lags could be quite variable across commodities. A consideration of actual trade flows tends to limit the reasonable range of delivery lags to be between one and four months. A straightforward means for choosing the optimal lag length involves the sample error objective functions for the alternative lag lengths $j = 0, \ldots, 4$. For the GMM estimator, the sample error objective function is given by

$$(8) \quad S(\gamma, V) = \left[\sum_{t=1}^{n} (e_t(\gamma) \otimes z_t)\right]' \cdot V^{-1}\left[\sum_{t=1}^{n} (e_t(\gamma) \otimes z_t)\right],$$

where

$$(9) \quad e_t(\gamma) = p_t - \beta_0 p_{t+j}^{*\beta_1} \pi_{t+j}^{\beta_2} + \tau_t,$$

$$(10) \quad V = \mathrm{Cov}\left\{\left[\sum_{t=1}^{n} (e_t(\gamma) \otimes z_t)\right], \left[\sum_{t=1}^{n} (e_t(\gamma) \otimes z_t)\right]'\right\},$$

$\gamma = \{\beta_0, \beta_1, \beta_2\}$ is the parameter set to be estimated, z_t is a vector of instruments, and $\otimes$ denotes the Kronecker product. Gallant (pp. 464–65) shows that the estimated GMM sample objective function $S(\cdot)$ offers a convenient model specification test. With the test of overidentifying restrictions, one rejects the hypothesis that the model is correctly specified when $S(\cdot)$ exceeds the upper $\alpha \times 100\%$ critical point of the chi-square distribution with $k - p$ degrees of freedom (where k is the number of instruments and p is the number of parameters being estimated). In this light, the "most correct" delivery lag specification minimizes the estimated value of $S(\cdot)$ and thus maximizes the significance level of the specification. The test of overidentifying restrictions also provides a convenient goodness-of-fit measure for comparing the lag lengths. Empirical support for an expectations-augmented view of the LOP will be generated in those cases where specifications with delivery lags ($j > 0$) are superior to that with no delivery lag ($j = 0$).[6]

Finally, actual transactions charges might be highly correlated across all basic agricultural commodities. In this light, a proxy measure of transactions charges will be constructed from a linear function of observable average monthly freight rates for wheat trade between the relevant markets, collected from the International Wheat Council's *World Wheat Statistics*.[7] Specifically, transactions costs are represented by

$$f(T_t) = \phi_0 + \phi_1 TW_t, \tag{11}$$

where TW_t is the quoted freight rate for wheat trade between the markets under consideration. This approach to representing transactions costs may have several weakness. First, freight rates for wheat may not provide an acceptable proxy for transactions costs for other commodities, especially the oilseed products, most notably, the oils. Second, freight rates do not include transportation costs between hinterland and export markets, risk premia and insurance, demurrage, handling fees, and information costs.

Under the assumptions outlined above, the basic econometric tests of the law of one price are specified by the following equations:

$$P_{it} = \alpha_0 + (P^*_{it})^{\alpha 1} - \alpha_2 TW_t, \tag{12}$$

$$P_{it} = \beta_0 + E_t\{(P^*_{it+j})^{\beta 1}\} - \beta_2 TW_t, \tag{13}$$

where $E_t\{P^*_{it+j}\}$ is the mathematical expectation of the value of P^*_i in time $t + j$, conditional on information available in time t, and TW_t is the proxy measure of per-unit transaction charges. The law of one price is rejected for the respective models when the parameters α_1 and β_1 are significantly different from one.

Formal tests of the law of one price for the standard and expectations-augmented versions of the basic model were conducted using the standard F and chi-square representations of the Wald test, respectively. The Wald test is discussed in detail in Judge et al. (pp. 182–87). The distinction between the standard F and chi-square representations of the Wald test occurs because denominator degrees of freedom are undefined in the GMM procedures.

The standard version of the law of one price, as represented by equation (12), was estimated using the conditional nonlinear least squares (NLS) procedures to correct for first-order autoregression. This procedure (Judge et al., pp. 287–89) is asymptotically equivalent to maximum likelihood if the residual errors are normally distributed. Such an explicit correction for autoregressive correlation is often employed in applications of the standard model (e.g., Protopapadakis and Stoll; Crouhy-Veyrac, Crouhy, and Melitz).

Parameter estimates and hypothesis testing results for the standard version of the law of one price are presented in table 2. In nearly every case the autoregressive parameter, ρ, is highly significant. Similarly, the price coefficients are highly significant in every case. Overall, the data are not inconsistent with the LOP theory. The price coefficient, α_1, lies within the interval [.90, 1.10] for thirteen of the seventeen markets.

The formal test of H_0: $\alpha_1 = 1$ is rejected at the 1% level of significance in eight of the seventeen cases. The test is supported for soybean meal, cottonseed meal, soybean oil, cottonseed oil, sunflowerseed oil, peanut oil, Wheat 4, Wheat 5, and corn. However, the remaining markets have price coefficients which are statistically different from one but are not so far from one as to be in strong conflict with price parity. The greatest deviation from parity conditions under the standard representation occurs for grain sorghum, which has a price coefficient

[6] The final choice of delivery lag is representative of the normal flow of commodities. It does not imply that individual transactions may not be quicker or take longer under special circumstances. Neither is the occasional resale of commodities at some point during shipment necessarily precluded by our specification.

[7] Specifically, the wheat market applications utilize the freight rates relevant to each comparison (U.S. Gulf, Pacific, or Atlantic export markets and Rotterdam or Japan import markets), while the oilseed market applications utilize freight rates for trade between the U.S. Gulf ports and Rotterdam.

Table 2. Standard Version of the LOP, Parameter Estimates, and Hypothesis Testing Results

Market	β_0	β_1	β_2	ρ	$P(x > F)$	R^2
Soybeans	37.0630	.9429	−.3083	.8653	.0001*[b]	.9739
(U.S./Rott.)	(12.0215)[a]	(.0092)	(.4583)	(.0640)		
Sunflrsd.	94.5351	.8793	1.4032	.8004	.0001*	.8584
(U.S./Rott.)	(24.2757)	(.0222)	(1.2992)	(.0809)		
Soybean Meal	−14.6764	.9850	.8789	.9885	.0105	.9901
(U.S./Rott.)	(9.5448)	(.0057)	(.3078)	(.0227)		
Ctnsd. Meal	95.3499	.8640	1.1814	.7941	.0114	.8148
(U.S./Rott.)	(27.1236)	(.0523)	(1.3227)	(.0777)		
Soybean oil	−54.6100	1.0023	2.2744	.9568	.7324	.9763
(U.S./Rott.)	(39.2007)	(.0067)	(1.5345)	(.0424)		
Ctnsd. oil	−110.0000	.9913	−1.8879	.4505	.2563	.9305
(U.S./Rott.)	(38.9128)	(.0076)	(1.7106)	(.1119)		
Sflrsd. oil	53.1994	.9955	5.4824	.6902	.5505	.9583
(U.S./Rott.)	(33.0304)	(.0075)	(1.5908)	(.0905)		
Peanut oil	−108.2900	.9751	−6.3752	.9370	.1266	.9149
(U.S./Rott.)	(115.5500)	(.0161)	(5.2305)	(.0460)		
Sflrsd. meal	42.0345	.8438	1.3951	.7881	.0001*	.8553
(U.S./Rott.)	(14.8264)	(.0358)	(.7539)	(.0761)		
Wheat 1	13.6538	.9605	.4021	.4940	.0018*	.9772
(U.S./Japan)	(4.2735)	(.0089)	(.1661)	(.1089)		
Wheat 2	16.8462	.9656	.5700	.4982	.0006*	.9874
(U.S./Japan)	(2.6675)	(.0059)	(.1182)	(.1042)		
Wheat 3	23.6006	.9444	.1276	.4488	.0028*	.8619
(U.S./Japan)	(10.1482)	(.0195)	(.3336)	(.1540)		
Wheat 4	13.2168	.9827	.8433	.3734	.0504	.9928
(U.S./Japan)	(2.0497)	(.0037)	(.1069)	(.1149)		
Wheat 5	5.7916	.9848	−.3286	.5062	.0197	.9656
(U.S./Rott.)	(4.5998)	(.0064)	(.2147)	(.0804)		
Wheat 6	7.9778	.9651	.0387	.5118	.0001*	.9765
(U.S./Rott.)	(3.9163)	(.0066)	(.1851)	(.1019)		
Corn	−3.9337	1.0013	.9337	.0947	.5899	.9912
(U.S./Rott.)	(1.4229)	(.0024)	(.0669)	(.1311)		
Grain sorghum	.2125	.8446	.0211	.8353	.0001*	.9282
(U.S./Rott.)	(.2617)	(.0321)	(.0098)	(.0565)		

[a] Numbers in parentheses are asymptotic standard errors.
[b] An asterisk indicates rejection of the LOP at the 1% level of significance.

of .8446. Adherence to the LOP for the standard model is especially limited in the wheat markets, with only two of the six markets supporting parity. Soybeans fail to support the standard version of the LOP.

McCloskey's distinctions between the statistical and economic significance of empirical results are especially relevant here.[8] In several cases, small standard errors result in statistical rejection of the LOP in cases where the price coefficients are close to one. However, in an economic sense, care should be used in interpreting these results as significant evidence against the LOP. In light of the evidence summarized by Officer (1989), the results provide some degree of support for price parity in international commodity markets because the price coefficients are generally closer to one than those usually obtained from the standard model.

The test of overidentifying restrictions utilized estimated sample error objective functions from the GMM estimates to select the most appropriate lag length from five specifications ($j = 0, \ldots, 4$ months) for each market. The test statistics and associated chi-square significance levels are given in table 3. The instrumental variables employed in the estimation were

$$z_{it} = \{1, p_{it-k}, p^*_{it-k}, r_{it-k}, TW_{it-k}, \pi_{it-k+1}\}, \quad \text{for } k = 1, 2; \tag{14}$$

[8] McCloskey notes: "In the usual test of purchasing power parity, a sample size of a million yielding a very tight estimate that $\beta = .999$, 'significantly' different from 1.0, could be produced under the usual procedures as evidence that the theory had 'failed'. Common sense, presumably, would rescue the investigator from asserting that . . . we should abandon purchasing power parity" (McCloskey, p. 202).

Table 3. Values of the Objective Function $S(\gamma, V)$ and Probabilities for the Test of Overidentifying Restrictions Under Alternative Lag Orders

Market \ Lag Order:	0	1	2	3	4
Soybeans	21.9914	17.9034*[a]	18.9511	18.8359	18.3836
(U.S./Rott.)	(.0049)[b]	(.0220)	(.0151)	(.0158)	(.0185)
Sunflrsd.	18.2044	17.2535*	17.3982	19.0235	18.9208
(U.S./Rott.)	(.0197)	(.0276)	(.0262)	(.0147)	(.0153)
Soybean meal	17.1793	17.1750*	19.0127	19.2986	17.8618
(U.S./Rott.)	(.0283)	(.0283)	(.0069)	(.0133)	(.0223)
Ctnsd. meal	18.8434	16.2752	16.1269*	16.8115	19.5020
(U.S./Rott.)	(.0157)	(.0386)	(.0406)	(.0321)	(.0124)
Soybean	19.3888	11.6415*	12.1545	13.7642	15.7358
(U.S./Rott.)	(.0129)	(.1679)	(.1444)	(.0881)	(.0463)
Ctnsd. oil	12.3472	11.5581*	13.4309	12.1822	17.6465
(U.S./Rott.)	(.1364)	(.1720)	(.0979)	(.1433)	(.0240)
Sflrsd. oil	13.5792	10.7725*	15.0915	19.8222	20.9613
(U.S./Rott.)	(.0934)	(.2149)	(.0574)	(.0110)	(.0073)
Peanut oil	14.9108	11.2252*	11.9108	14.3234	14.0007
(U.S./Rott.)	(.0609)	(.1892)	(.1552)	(.0737)	(.0817)
Sflrsd. meal	14.2468	14.3277	13.5265*	14.3405	13.5471
(U.S./Rott.)	(.0756)	(.0736)	(.0950)	(.0733)	(.0944)
Wheat 1	11.8973	5.3615*	9.4532	20.0394	19.0115
(U.S./Japan)	(.1558)	(.7183)	(.3055)	(.0102)	(.0148)
Wheat 2	16.9432	12.9034*	14.5915	15.1687	28.1881
(U.S./Japan)	(.0307)	(.1152)	(.0676)	(.0559)	(.0199)
Wheat 3	24.4811	18.8201	14.3876	8.8607*	9.1758
(U.S./Japan)	(.0019)	(.0159)	(.0722)	(.3542)	(.3277)
Wheat 4	7.3386	6.4698*	9.4819	12.7060	15.3193
(U.S./Japan)	(.5006)	(.5948)	(.3033)	(.1224)	(.0532)
Wheat 5	16.1883	7.6833*	10.5636	8.7178	9.0284
(U.S./Rott.)	(.0398)	(.4650)	(.2276)	(.3667)	(.3399)
Wheat 6	19.9570	15.7225*	15.9635	18.5729	18.4800
(U.S./Rott.)	(.0105)	(.0408)	(.0429)	(.0153)	(.0179)
Corn	13.4422*	16.6850	21.1208	22.5465	21.7945
(U.S./Rott.)	(.0975)	(.0336)	(.0068)	(.0040)	(.0053)
Grain sorghum	20.8822	20.0282*	20.2222	23.3744	23.1451
(U.S./Rott.)	(.0075)	(.0102)	(.0095)	(.0029)	(.0032)

[a] An asterisk indicates the minimal value across the alternative lag orders.
[b] Chi-square probabilities for each value of $S(\cdot)$ are given in parentheses.

where r_{it} is the interest rate on U.S. federal funds, collected from the U.S. Department of Commerce's *Business Conditions Digest* series, and π_{it} is an exchange rate relevant to trade in the market under consideration, collected from the International Monetary Fund's *International Financial Statistics* series.

Except for the corn market, the test of overidentifying restrictions concludes in favor of a specification which incorporates delivery lags. In several cases, the test statistic $S(\cdot)$ declines significantly when going from no delivery lag to lagged price relationships. The minimal value of the test of overidentifying restrictions statistics across the five lag alternatives indicates the probability-maximizing specification and thus indicates the optimal lag order choice. Thirteen of the seventeen markets have optimal lag orders of a single month. Results suggest an optimal lag order of two months for cottonseed meal and sunflowerseed meal and three months for the Wheat 3 market.[9] In every case, the hypothesis that the optimal lag order yields a correct specification at the 1% level of significance is not rejected. In all, such results strongly favor an expectations augmented view of the LOP.

Parameter estimates and hypothesis testing results for the expectations augmented version of

[9] Wheat 3 is a northern spring wheat moving out of the Gulf ports. Although prices are taken at the Gulf, the longer lag length may reflect the greater logistical arrangements associated with exporting grain which originates in northern interior regions through the Gulf to Japan.

the law of one price are presented in table 4. Estimation was accomplished using the GMM procedures and was made conditional on the preceding choice of optimal lag lengths.[10] The price coefficients are highly significant in every case and are numerically closer to the theoretically implied value of one than are the price coefficients for the standard model in twelve of seventeen cases. In four of the five remaining cases, the differences between the estimated price coefficients for the standard and expectations-augmented versions of the LOP are less than .015.

The results of formal hypothesis testing for the expectations augmented version of the LOP support parity in fourteen of the seventeen cases.[11] The LOP is rejected for cottonseed oil, sunflowerseed meal, and Wheat 5. The LOP is supported in every case considering trade between the United States and Japan. The results support parity between prices in U.S. and Rotterdam markets in ten of thirteen cases. With the possible exception of sunflowerseed meal, which has a price coefficient of .9003, none of the commodities are in strong violation of the LOP. A price coefficient with a value of .90 does provide tempered support for the LOP.

[10] The results for the corn market are conditional on a lag order of zero. Thus, for the corn market, the revised model specification is identical to the standard specification of a contemporaneous price relationship. The application differs only with respect to the econometric technique used for estimation.

[11] In eleven of the seventeen cases, the parameters of the expectations-augmented version of the LOP have slightly larger standard errors than those of the standard version. However, under our argument for an alternative expectations-augmented model, the standard model parameter estimates and standard errors are subject to specification biases. In no case does this result allow the LOP to be supported by the reformulated version and rejected by the standard version when the price coefficient for the reformulated version is actually numerically farther from one.

Table 4. Revised Version of the LOP, Parameter Estimates, and Hypothesis Testing Results

Market	β_0	β_1	β_2	$P(x > \chi^2)$
Soybeans	−12.5671	.9963	1.1601	.7611
(U.S./Rott.)	(16.1117)[a]	(.0121)	(.6633)	
Sunflrsd.	11.1371	.9761	3.4907	.4043
(U.S./Rott.)	(36.9786)	(.0286)	(.9387)	
Soybean meal	1.7407	.9983	1.7373	.7810
(U.S./Rott.)	(8.4902)	(.0062)	(.5312)	
Ctnsd. meal	69.6257	.9803	4.7002	.0990
(U.S./Rott.)	(11.6283)	(.0119)	(1.0277)	
Soybean oil	−39.6546	1.0084	1.9828	.4441
(U.S./Rott.)	(32.5856)	(.0109)	(1.6663)	
Ctnsd. oil	−249.7773	1.0200	−3.2944	.0040*[b]
(U.S./Rott.)	(35.8933)	(.0069)	(1.2782)	
Sflrsd. oil	4.0785	1.0188	8.7542	.0664
(U.S./Rott.)	(41.3216)	(.0102)	(1.1872)	
Peanut oil	231.1752	1.0053	27.1543	.5909
(U.S./Rott.)	(68.6099)	(.0099)	(5.2536)	
Sflrsd. meal	37.7617	.9003	2.9396	.0001*
(U.S./sRott.)	(7.2728)	(.0121)	(.4823)	
Wheat 1	−4.8468	1.0153	1.5337	.1960
(U.S./Japan)	(4.7893)	(.0118)	(.2995)	
Wheat 2	9.5853	.9911	1.1406	.2523
(U.S./Japan)	(3.1322)	(.0078)	(.1797)	
Wheat 3	−16.5227	1.0483	2.5012	.0272
(U.S./Japan)	(11.7575)	(.0219)	(.6976)	
Wheat 4	5.2791	1.0075	1.5990	.3097
(U.S./Japan)	(2.9093)	(.0074)	(.2546)	
Wheat 5	−16.8319	1.0265	1.8691	.0008*
(U.S./Rott.)	(5.9108)	(.0079)	(.3216)	
Wheat 6	7.5459	.9663	.0099	.0159
(U.S./Rott.)	(6.4205)	(.0140)	(.3846)	
Corn	−3.0144	1.0018	1.0374	.3389
(U.S./Rott.)	(1.3270)	(.0019)	(.0508)	
Grain sorghum	−.4780	1.0167	.1138	.5244
(U.S./Rott.)	(.1583)	(.0262)	(.0153)	

[a] Numbers in parentheses are asymptotic standard errors.
[b] An asterisk indicates rejection of the LOP at the 1% level of significance.

A Nonparametric Test of the Law of One Price

A possible weakness of regression-type tests of the LOP involves inferential biases in situations where prices vary in a nonsynchronous manner within the band created by transactions costs. Under such circumstances, the LOP may be erroneously rejected. However, under such conditions, trade is not profitable and thus should not occur. In this light, concerns of such biases are tempered when a continuous flow of commodities is observed between the markets in question (as occurs for all of the markets in this analysis). Alternatively, adherence to the LOP might be incorrectly supported by regression-type tests when price changes in spatially separated markets move in a synchronous manner outside of the transactions cost band.[12]

An alternative approach to testing international parity relationships has been developed by Frenkel and Levich. This approach employs nonparametric tests that involve estimating the transactions costs band and counting the observations outside of the band. Such observations imply *ex post* profit opportunities. However, such tests are conditional upon the correct measurement of transactions costs.

Frenkel and Levich's nonparametric tests were applied to the six wheat commodities in this analysis. Direct observations of actual freight rates were only available for these commodities. Frenkel and Levich consider the role of transaction timing by examining noncontemporaneous parity relationships.[13] In a similar manner, the nonparametric procedures were applied to the noncontemporaneous price linkages implied by the previously identified delivery lags as well as to contemporaneous price comparisons.

The results of the nonparametric tests are presented in table 5. In five of the six cases, fewer observations violate the conditions for parity when delivery lags are explicitly recognized. *Ex post* arbitrage profits are given by the difference between price differentials and transactions costs. In three of the six cases, the incorporation of delivery lags results in smaller mean implied profits. However, in every case, the t-ratios for the mean-implied profits are smaller when delivery lags are recognized, implying less significant profit levels. The magnitude of the differences between the alternative tests is often quite small. However, the results are similar in magnitude to those obtained by Frenkel and Levich and provide similar support for an expectations augmented view of price parity.

Though the nonparametric tests provide additional evidence in favor of an expectations-augmented view of the LOP, this approach also has its limitations. In particular, the nonparametric tests depend upon the correct measurement of transactions costs. Such measurement may be relatively straightforward in the financial markets considered by Frenkel and Levich. However, Bahmani-Oskooee and Das, and Clinton have criticized Frenkel and Levich's measurement approach. Physical commodity trade is much more complex than financial arbitrage and presents greater difficulties in measuring transactions costs, as illustrated earlier in the article. Thus, the nonparametric results should be interpreted with considerable care.

Concluding Comments

The empirical literature has produced only weak support for the law of one price. However, typical representations have compared contemporaneous prices in geographically separate markets. These tests fail to incorporate time lags, which are potentially important in spatial arbitrage. When time lags are considered, expected future prices must be included in the analysis. In addition, standard approaches to testing parity conditions have neglected to consider transportation costs in specific terms.

This paper pursues two distinct approaches to testing the LOP. The first approach uses the generalized method of moments econometric procedures to estimate rationally formed expected future prices. Actual freight rates for wheat trade are utilized to provide a proxy measure of transactions costs. To focus on the role of expected prices, a comparison was made between dollar prices in the United States and other countries for seventeen homogenous agricultural products. A second approach employs a nonparametric analysis of price parity using the actual freight rates for trade between several important wheat markets.

Under each approach, empirical results using a simple expectations-augmented model pro-

[12] This criticism is analogous to the well-recognized problem of spurious correlation. Such a criticism is equally applicable to any regression test of economic equilibrium conditions. Because this situation would imply persistent profit opportunities, it is precluded by highly efficient markets.

[13] Frenkel and Levich apply a simple trading rule according to which investors calculate a profit signal at period t and execute their transactions at period $t + 1$ (using weekly security price quotes). Their approach is analogous to the use of delivery lags in this study.

Table 5. Nonparametric Tests of the LOP for Wheat, Contemporaneous and with Delivery Lags

Market	n	No. Observations Outside Band	Percentage of Observations Outside Band	Average Profits
Contemporaneous Tests				
Wheat 1	69	56	81.16	.0287
(U.S./Japan)				(6.5474)[a]
Wheat 2	76	33	43.42	−.0012
(U.S./Japan)				(−.3871)
Wheat 3	76	41	53.95	.0045
(U.S./Japan)				(.6654)
Wheat 4	76	33	43.42	−.0034
(U.S./Japan)				(−1.1887)
Wheat 5	125	71	56.80	.0029
(U.S./Rott.)				(1.1077)
Wheat 6	76	71	93.42	.0505
(U.S./Rott.)				(14.1807)
With Delivery Lags				
Wheat 1	68	50	73.53	.0332
(U.S./Japan)				(4.6583)
Wheat 2	75	37	49.33	.0010
(U.S./Japan)				(.1741)
Wheat 3	73	32	43.84	.0061
(U.S./Japan)				(.5047)
Wheat 4	75	32	42.67	−.0025
(U.S./Japan)				(−.4440)
Wheat 5	124	66	53.23	.0027
(U.S./Rott.)				(.6465)
Wheat 6	75	59	78.67	.0456
(U.S./Rott.)				(6.6074)

[a] Numbers in parentheses are t-ratios for the means.

duce greater support for the LOP than the same model using contemporaneous prices. Specification testing with the test of overidentifying restrictions and the subsequent applications of the expectations augmented version of the LOP support contentions that price parity is more likely when price expectations are given explicit attention. The LOP appears quite strong in international markets for U.S. agricultural products. Hence, the outcomes of previous tests may have been influenced by inadequate spatial price linkages and by a neglect of the transactions costs associated with international commodity exchange.

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Exchange Rate Risk and U.S. Agricultural Trade Flows

Daniel H. Pick

This paper analyzes the effect of exchange rate risk on U.S. agricultural trade flows. A model which incorporates exchange rate risk is applied to ten countries. While exchange rate risk was not significant in the seven developed markets, results indicate that the exchange rate variable adversely affected U.S. agricultural exports to the three developing countries used in the analysis. These findings underscore the importance of exchange rate risk in developing countries trading behavior. Issues such as establishment of well-developed financial and commodity markets in developing countries must be addressed in future research.

Key words: agricultural exports, developing countries, exchange rate risk.

The effects of exchange rates on agricultural trade was raised by Schuh (1974, 1976) and was followed by numerous efforts to quantify the effects of the nominal exchange rate on trade (Chambers and Just 1979, 1981; Konandreas, Bushnell, and Green; and others) or the effects of the real exchange rate on trade (Longmire and Morey; Batten and Belongia; Henneberry, Henneberry, and Tweeten). A neglected issue in those studies is the impact of exchange rate risk on agricultural trade flows (Williamson, Kenen and Rodrik, Anderson and Garcia).

In this paper, a model which incorporates exchange rate risk is applied to ten countries to evaluate the impact of exchange rate risk on agricultural bilateral trade flows. The first section will present the development of the conceptual model. This is followed by the data and estimation results. Finally, conclusions and implications are drawn.

Exchange Rate Risk and Model Specification

Studies of the effects of exchange rate risk on trade by Clark, Hooper and Kohlhagen, Gotur, Cushman (1983, 1988), De Grauwe, Maskus, and others postulate that exchange rate risk reduces trade. However, earlier results (Hooper and Kohlhagen) lend little support to this hypothesis; although Cushman (1988), by using measures of real exchange rate risk, found significant adverse effects of exchange rate risk on U.S. trade flows.

The model (adopted from Hooper and Kohlhagen) assumes that the demand for imports is a derived demand, where imports are used in the domestic production of the final goods. This assumption is particularly true in agricultural trade since most goods are intermediate in nature. Further, the importer faces a domestic demand for its output, Q, which is a function of domestic income Y, price of other goods (substitutes and complements), PD, and own price, P:

$$Q = aP + bPD + cY. \tag{1}$$

The risk-averse importer is assumed to maximize expected utility with respect to profits. (Utility is assumed to be an increasing functon of profits and a decreasing function of the standard deviation of profits.) While the importer receives orders for its output in the first period, it only pays for the imports and receives payments for its output in the second period. Thus, prices are determined in the first period and the expected utility problem is

$$\max_{Q} EU(\pi), \tag{2}$$

where E is expectations, U is utility and π is profits.

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Assuming a constant input-output ratio, the input can be presented as

$$q = \lambda Q, \tag{3}$$

where q is total input and λ is the fixed input-output coefficient. Thus, the importer's profits are

$$\pi = QP(Q) - UC \cdot Q - HP^*\lambda Q, \tag{4}$$

where UC is the unit cost of production, H is the foreign exchange variable, and P^* is the import price in the foreign currency.

The model distinguishes between imports denominated in the importer's and the exporter's currency. It further distinguishes between imports denominated in the exporter's currency and hedged versus unhedged in the forward exchange market. The foreign exchange cost variable can be presented as

$$H = \beta(\mu F + (1 - \mu)R_1) + (1 - \beta)F, \tag{5}$$

where β is the share of imports denominated in the exporter's currency, $(1 - \beta)$ is the share of imports denominated in the importer's currency, μ is the proportion of foreign currency costs hedged in the forward market, F is the forward cost of the exporter's currency in terms of the importer's currency, and R_1 is the spot exchange rate realized in the second period.

Denoting the price of imports in the exporter's currency as P^*, and q as the quantity of inputs imported, then the costs of importing the share denominated in the importing country's currency is $(1 - \beta)FP^*q$. The cost of the proportion denominated in the exporter's currency and hedged in the forward exchange rate market is $\beta\mu FP^*q$. The cost of the proportion of imports denominated in the exporter's currency and not hedged in the forward exchange market is then $\beta(1 - \mu)R_1P^*q$. Given the definition of H, if all imports are denominated in the importer's currency ($\beta = 0$) or all imports which are denominated in foreign currency are hedged ($\mu = 1$), then the costs of imports would be known with certainty. However, the most likely case is that $\beta > 0$ and $\mu < 1$, and uncertainty is introduced since R_1 is unknown in the first period.

While the magnitudes of β and μ are unknown, most of U.S. agricultural exports are denominated in U.S. dollars, and not all foreign exchange involved in the transaction is hedged in the forward exchange market. For example, McCalla and Schmitz note that world grain trade, which accounts for over one-third of U.S. agricultural exports, is primarily denominated in U.S. dollars. Thus $\mu < 1$, and importers are facing exchange rate risk in their import transactions with the United States.

Assuming that $\beta > 0$, $\mu < 1$, and the introduction of uncertainty by the exchange rate variable R_1, the variance of profits is

$$V(\pi) = [P^*\lambda Q\beta(1 - \mu)]^2\sigma^2_{R1}, \tag{6}$$

where σ^2_{R1} is the variance of R_1.

Exporter's behavior can be modeled in a similar fashion:

$$\text{Max } EU^*(\pi^*), \tag{7}$$

where the asterisk denotes exporter's variables. Exporter's profits can be presented as

$$\pi^* = q^*P^*H^* - q^*UC^*. \tag{8}$$

Hooper and Kohlhagen use the above specifications of the exporter's and importer's expected utility maximization problem to derive the nonlinear reduced-form equilibrium equation for the quantity exported. However, they used a linear approximation in their final estimation procedure because of statistical difficulties.

Cushman (1983) extended the Hooper and Kohlhagen model by defining profits in real terms; and this approach was then further utilized by Cushman (1988) and Kenen and Rodrik, who used the following reduced-form equation:

$$Q^* = \alpha + \eta Y + \rho UC_{im} + \phi UC_{ex} + \xi R + \kappa M + \upsilon S, \tag{9}$$

where Q^* is the real export value (as a measure of quantity), Y is the importer's real income (GNP), UC_{im} is the importer's real unit production cost, UC_{ex} is the exporter's real unit production cost, R is the foreign currency per U.S. dollar exchange rate, M is a four-quarter moving-average of recent percentage change in R, which is a proxy for the expectations of the uncertain growth rate of the real exchange rate defined in Cushman 1983, and S is a risk measure representing the uncertain growth rate of the real exchange rate.[1]

Equation (9) provides the basis for the empirical application. The expected sign for the income variable is positive, indicating that as real income in the importing country rises so will the quantity exported. UC_{im} and UC_{ex} are expected

[1] Cushman (1983) formulated the uncertain component of the exchange rate as $R_1 = R_0\theta$, where R_0 is the known current real exchange rate and θ is the uncertain growth rate of R.

to have negative coefficients although a positive coefficient is possible for the UC_{tm} variable (Cushman 1988). A negative coefficient is expected for the foreign exchange variable because appreciation of the U.S. dollar (increase in R) will lead to decrease in exports. M and S (assuming risk-averse agents) are expected to be negative.

Data

Quarterly data from 1978–87 were used in the empirical analysis. Ten countries were included in this study: Japan, South Korea, Canada, Australia, West Germany, France, Netherlands, United Kingdom, Brazil, and Mexico. Collectively, these countries accounted for over 51% of U.S. agricultural exports in 1988. Agricultural (value) export data from the United States to these countries were obtained from the Department of Commerce.

Quarterly gross national product (GNP) data as well as the consumer price index (CPI), wholesale price index (WPI), and exchange rates (foreign currency per U.S. dollar) data were obtained from *International Financial Statistics* published by the International Monetary Fund. Since continuing quarterly data of GNP for Netherlands and South Korea were not available, gross domestic product (GDP) was used as the income variable for these countries. CPI's were used as price deflators to obtain estimates of real GNP and real exchange rates.[2]

Unit costs of production were obtained by using indices of prices paid by farmers. The index of prices paid by U.S. farmers for production items, interest, taxes, and wage rate was obtained from *Agricultural Prices* published by USDA Agricultural Statistics Board. For the EEC countries of West Germany, Netherlands, France, and United Kingdom, the purchase price indices of the means of agricultural production for each of the countries were obtained from *EC Agricultural Price Indices* published by Eurostat. For Canada, total farm input price indices were obtained from *Farm Input Price Index* published by Statistics Canada. Price indices of all commodities purchased by farmers were used for Japan. These indices were found in *Monthly Statistics of Agriculture Forestry and Fishery* published by the Japanese Ministry of Agriculture, Forestry and Fishery. In the case of South Korea, price indices of all farm supplies, goods, wages and charges were obtained from the *Monthly Review* published by the National Agricultural Cooperative Federation. Average price indices paid by farmers in the states of Victoria and New South Wales was used for Australia. These data were obtained from *Indexes of Prices Received and Paid by Farmers* published by the Australian Bureau of Agricultural and Resource Economics.

Estimation and Results

The first step in the empirical analysis was to construct the exchange rate risk proxy (S). Following Cushman (1988), two measures of exchange rate risk were used. Each measure assumes that traders use variability of the exchange rate in deviation form as a risk proxy. The first, (S_1), is a moving four quarters standard deviation of the relative change in the real exchange rate. The second, (S_2), is similar to S_1 except that it is based on monthly observations, and therefore, is calculated as a moving twelve months standard deviation of relative changes in the real exchange rate; S_1 assumes that quarterly variations affect trade, while S_2 assumes that monthly variations affect trade.

Equation (9) was estimated using a double log specification (except the risk variable which takes negative values) for each importing region. Data limitations required changes in the specification of some equations. The equation for Brazil was estimated without the income variable because no quarterly GNP (or GDP) exist for this country. The wholesale price index (WPI) was substituted as a proxy for unit cost of production in Brazil and Mexico because data were unavailable for this latter variable.

Each equation was first estimated using ordinary least squares (OLS). Non-risk variables which generated a t-value of close to zero were omitted from the equation. Equations which exhibited autocorrelation were corrected using the iterative Yule-Walker procedure offered in SAS. Cushman's (1988) approach was adopted by estimating (9), first with S_1 as the risk measure. The initial lag was set at one, although different lags provided better results for some variables. Once the lag length was determined for each of

[2] David Stallings (USDA ERS) provided the exchange rate data in both nominal and real terms.

the variables, equation (9) was estimated again with S_2 as the risk variable.[3]

Because short-run (quarterly) data were used in the analysis, the lag length for the risk variable is not known, and different lags were tested. Coefficients of the equations which yielded the "best" results with S_1 as the risk variable are reported in table 1, while those with S_2 as the risk measure are reported in table 2. Overall, the equations performed relatively well, considering the usual problems of using aggregate data.

The results with S_1 as the risk proxy in table 1 reveal some interesting outcomes. In seven out of the ten equations, the bilateral real exchange rate variable (R) was negative and significantly different than zero at the 90% level. In two of the remaining equations (West Germany and Australia), the exchange rate coefficient was also negative but significant at only the 85% level. These results suggest that as the real value of the U.S. dollar appreciates (R increases), agricultural imports by these countries decrease. Thus, the importance of the real exchange rate in determining agricultural trade flows is confirmed.

[3] The determination of the appropriate lag length when using quarterly data poses a problem because the lag structure which affects the dependent variable is unknown. Cushman's (1988) approach was utilized by estimating each equation with different lag specification and arriving at the "best" (as Cushman states) equation. While this approach is ad hoc, it provides a way of observing alternative lag specifications.

Batten and Belongia; and Henneberry, Henneberry, and Tweeten found that the real exchange rate significantly affected U.S. agricultural exports. However, both studies used a single real trade weighted exchange rate in their analysis. Our findings demonstrate that bilateral real exchange rates are also important in determining agricultural trade flows.

The income variable (Y) is positive for all countries and significantly different than zero for the United Kingdom, Australia, Japan, and South Korea. Because the equations were estimated in double log form, the coefficients can be interpreted as elasticities. They indicate that high income elasticities generally exist, except for Canada and Mexico. In two countries, France and Netherlands, the income coefficients are 1.03 and 1.05, respectively, indicating an almost unitary income elasticity.

The unit cost of production variable in the importing region (UC_{im}) is positive in seven out of the ten countries. It implies that as production costs in the importing countries increase, imports will increase as well. In Japan and Brazil this variable was both significant and negative. The negative sign indicates that as the unit cost of production in the importing region rises, the price of the domestically produced product also rises. The rise in the domestic price will lower demand for the product and, thus, the import demand for intermediate goods declines. The unit cost of production variable in the exporting

Table 1. U.S. Export Equations with S_1

	United Kingdom	West Germany	France	Netherlands	Canada	Australia	Japan	South Korea	Brazil	Mexico
Intercept	−22.62	29.31	−8.35	19.37	14.35	−44.25	−1.60	11.01	56.11	−26.26
	(−1.61)	(0.52)	(−0.17)	(1.17)	(1.62)	(−2.47)	(−0.09)	(0.70)	(1.59)	(−1.58)
Y	2.97[a]	1.36[b]	1.03[a]	1.05[c]	0.43[a]	2.74[c]	2.86[b]	1.30[c]		0.66[c]
	(3.10)	(0.32)	(0.31)	(0.80)	(0.74)	(1.95)	(2.27)	(2.34)		(1.31)
UC_{im}	5.00[a]	6.52[a]	5.05[a]	3.28[b]	1.13[a]	2.82[b]	−4.92[b]	−0.40[a]	−0.19[a]	0.21[a]
	(3.48)	(2.07)	(1.33)	(2.54)	(1.53)	(1.91)	(−2.28)	(−0.44)	(−1.76)	(2.23)
UC_{ex}		−11.39[b]	−1.86[a]	−5.09[b]	−1.75[c]	5.71[c]	1.66[b]		−8.11[a]	8.18[a]
		(−2.60)	(−0.45)	(−1.31)	(−1.79)	(2.28)	(0.81)		(−1.19)	(2.44)
R	−0.83[b]	−0.53[c]	−1.12[a]	−0.62[b]	−2.31[b]	−1.01[b]	−0.96[a]	−1.57[c]	0.67[a]	−1.89[a]
	(−4.29)	(−1.56)	(−2.77)	(−2.43)	(−3.67)	(−1.54)	(−2.70)	(−1.97)	(0.77)	(−4.14)
M		−0.09[b]			−0.04[c]		−0.04[b]			0.15[c]
		(−1.47)			(−2.67)		(−2.28)			(1.68)
S	−0.83[a]	−1.62[a]	−2.67[a]	−0.70[a]	−1.86[b]	−0.45[b]	−0.95[a]	−3.90[b]	−7.45[a]	−2.80[a]
	(−0.78)	(−0.76)	(−1.06)	(−0.36)	(−1.41)	(−0.21)	(−1.08)	(−2.04)	(−1.97)	(−3.33)
R^2	0.64	0.51	0.39	0.31	0.70	0.28	0.37	0.63	0.45	0.68
Adj R^2	0.58	0.41	0.29	0.19	0.49	0.17	0.24	0.43	0.42	0.65
D.W.	1.95	1.97	2.10	1.87	*[d]	1.95	1.94	*	*	*

[a] No lags.
[b] One quarter lag.
[c] Two quarters lag.
[d] Asterisk indicates D-W was not reported since these equations were corrected for autocorrelation.

Table 2. U.S. Export Equations with S_2

	United Kingdom	West Germany	France	Netherlands	Canada	Australia	Japan	South Korea	Brazil	Mexico
Intercept	−17.74	15.51	−36.37	22.69	15.47	−55.93	13.18	20.26	32.10	−29.05
	(−1.27)	(0.28)	(−0.85)	(1.30)	(1.72)	(−2.47)	(0.70)	(1.47)	(0.97)	(−1.74)
Y	2.65[a]	2.46[b]	2.93[a]	1.11[c]	0.28[a]	3.31[c]	1.86[b]	0.81[c]		0.78[c]
	(2.65)	(0.58)	(0.97)	(0.90)	(0.47)	(2.56)	(1.31)	(2.01)		(1.59)
UC_{im}	5.29[a]	7.41[a]	6.02[a]	3.93[b]	0.99[a]	2.83[b]	−3.98[b]	−0.11[a]	−0.13[a]	0.11[a]
	(3.30)	(2.28)	(1.60)	(2.94)	(1.30)	(2.00)	(−2.20)	(−0.14)	(−1.21)	(1.30)
UC_{ex}		−11.06[b]		−6.42[b]	−1.68[c]	7.53[c]			−3.56[a]	8.38[a]
		(−2.54)		(−1.59)	(−1.68)	(3.23)			(−0.55)	(2.52)
R	−0.76[b]	−0.45[c]	−1.22[a]	−0.56[b]	−1.95[b]	−1.10[b]	−0.74[b]	−1.39[c]	0.44[a]	−1.55[a]
	(−3.61)	(−1.26)	(−3.00)	(−2.32)	(−3.37)	(−1.79)	(−1.84)	(−1.85)	(0.50)	(−3.30)
M		−0.09[b]			−0.04[c]		−0.04[b]			0.11[c]
		(−1.48)			(−2.77)		(−2.20)			(1.30)
S	−3.57[a]	−4.96[a]	−4.40[a]	−4.44[b]	−2.74[c]	−9.35[b]	−3.05[b]	−5.39[b]	−4.25[b]	−4.56[a]
	(−1.16)	(−0.68)	(−0.66)	(−0.67)	(−0.75)	(−1.68)	(−1.27)	(−1.57)	(−0.82)	(−3.75)
R^2	0.58	0.51	0.34	0.33	0.68	0.39	0.37	0.61	0.39	0.71
Adj R^2	0.51	0.40	0.23	0.22	0.47	0.30	0.23	0.40	0.36	0.66
D-W	1.94	1.95	2.03	1.91	*[d]	1.93	1.84	*	*	*

[a] No lags.
[b] One quarter lag.
[c] Two quarters lag.
[d] Asterisk indicates D-W was not reported since these equations were corrected for autocorrelation.

country (United States) was included in eight countries. The coefficient was negative in five countries, indicating that as the unit cost of production in the United States increases less will be demanded in the importing country.

The moving average of the change in the real exchange rate variable was included in only four equations, generating the expected negative sign in three of the cases. The coefficients are significant for Canada and Japan and positive and significant (90%) for Mexico.

The risk variable (S_1), as expected, is negative in all ten countries and significantly different than zero in South Korea, Brazil, and Mexico. A negative sign for the risk coefficient indicates that as risk increases trade decreases. One can make a general observation regarding the risk coefficients.

In the three developing countries analyzed in this study (South Korea, Brazil, and Mexico), the risk coefficient was negative and significantly different than zero. Either developing countries do not hedge against exchange rate risk or their financial markets are not well developed. This conclusion is supported by Quirk et al., who studied the forward exchange markets in developing and developed markets. Furthermore, Coes and Diaz-Alejandro found that exchange rate risk adversely affected trade in Brazil and Colombia, both of which are developing countries.

Developed countries, on the other hand, use different hedging strategies (futures and forward markets) to eliminate exchange rate risk. The negative but insignificant risk coefficients in the developed countries also suggest the use of well-developed financial markets to hedge against exchange rate risk.

These results are consistent with the findings of Collins, Meyers, and Bredhal. They found that exchange rate effects on domestic prices were more pronounced under nominal exchange price insulation policies than under free trade. Therefore, it is not surprising that exchange rate risk plays an important role in developing countries where imports are highly restricted and centralized.

Table 2 summarizes the results of the equations when S_2 was used as the risk proxy. The risk variable becomes insignificant in South Korea and Brazil and remained significant in Mexico. In Australia, the risk coefficient is close to being significant at the 90% level. Otherwise, the results were not substantially different than those reported in table 1. Although the distinction between the results for the developed countries and developing countries is not as strong as those with S_1 as the risk measure, these results do not discount those obtained using the S_1 measure. The risk coefficients, for both S_1 and S_2, which were significantly different than zero were obtained only for developing countries.

Comparison of the results to other studies is difficult because of the different nature of this study. However, some general observations can be made. Anderson and Garcia found that ex-

change rate risk has a significant adverse effect on exports to three developed countries: France, Japan, and Spain. Their results were obtained from a disaggregated analysis. Perhaps exchange rate risk plays a more prominent role in trade of particular agricultural commodities compared with aggregate agricultural trade.

Cushman (1988) and Kenen and Rodrik found more significant adverse effects of exchange rate risk on exports to developed markets than the results of this study. One would expect exchange rate risk to be less significant in food products than industrialized products; agricultural products are considered necessities and, therefore, less sensitive to exchange rate variability.

Our results are somewhat contradictory to those obtained by Maskus (p. 23), who stated that "agricultural trade was the most susceptible to exchange rate uncertainty." His results, however, produced a significant negative risk coefficient only for U.S. agricultural exports to Germany. On the other hand, nonsignificant risk coefficients were obtained for Japan, United Kingdom, and Canada.

Concluding Comments

This paper analyzes the effects of exchange rate risk on U.S. agricultural exports to ten different countries. A model which incorporates exchange rate risk was formulated and estimated. Two measures of exchange rate risk were constructed. While the results suggest that the real exchange rate is significant in determining U.S. agricultural exports, they do not indicate that exchange rate risk is always important. The results with regard to the exchange rate risk variable (S_1 and S_2) were not significant in the seven developed markets. However, the risk variable S_1 was negative and significant in the three developing markets of Brazil, Mexico, and South Korea, indicating that exchange rate risk adversely affected U.S. agricultural exports to these countries.

These findings underscore the importance of exchange rate risk in developing countries' trading behavior. Issues such as establishment of well-developed financial and commodity markets in developing countries must be considered at both aggregate and specific commodity levels (Anderson and Garcia), so that the nature of exchange rate risk can be better understood.

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Grain Price Expectations of Illinois Farmers and Grain Merchandisers

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The study's purpose is to measure the extent to which futures and option prices reflect the subjective price distribution of a subset of market participants, farmers, and grain merchandisers in Illinois. Findings suggest that in most instances the futures price is an appropriate proxy for expected price. However, volatilities implied by option premia usually overestimate the subjective variances of producers and merchandisers. These differences between individual and market expectations of variance are consistent with findings of overconfidence in the psychology literature and should be considered by analysts when making observations about hedging decisions and risk aversion.

Key words: implied volatilities, judgment, options and futures markets, price expectations, subjective distributions.

Little empirical attention has been given to the relationship between the prices, or implied price distributions, quoted on organized futures and options markets and the subjective expectations of individuals. Yet, this issue is central to the validity of many studies that use the futures price as a proxy for expected price (e.g., Gardner, Helmberger and Akinyosoye, Just and Rausser). This issue is also important because the relationship between expectations and futures and options prices is fundamental to most hedging decisions. The purpose of this study is to measure the extent to which futures and option prices reflect the subjective price distribution of a subset of market participants, farmers and grain merchandisers in Illinois.

One of the reasons individual expectations may not agree with futures and option prices is that the expectations of individuals may not accurately reflect the underlying distribution of prices; that is, individual probability assessments may not be well calibrated with the distribution of actual outcomes. As a result of "anchoring," people systematically misestimate the probabilities of uncertain events (Tversky and Kahneman, Kahneman and Tversky).[1] In addition, evidence suggests that people often are "overconfident"; that is, their probability distributions are too narrow.[2]

Market and individual expectations may also differ because market expectations reflect an assessment made by a group. Sniezek and Henry found that group judgments are significantly more accurate than mean or median individual judgments, and that group judgments are not accurately described by averages of the assessments of individual group members. However, they also found that groups are no less (over)confident in their assessments than individuals.

Given these findings, it is plausible that individual probability assessments would display overconfidence. Moreover, the probability assessments of futures markets, representing a group judgment, would be more accurate than individual assessments but may not display less overconfidence than individual assessments. Therefore, a lack of agreement between the fu-

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[1] Anchoring refers to the process of forming estimates of uncertain events or quantities by adjusting from an initial value. The initial value may be obtained in a number of ways, e.g., in the formulation of the question or some historical value. Generally, adjustments from the anchor are insufficient and the resulting estimate is poorly calibrated.

[2] Overconfidence has been found to be related to the difficulty of the prospect being assessed and to the time horizon between the assessment and the occurrence of the event. For a review of literature related to overconfidence and other calibration issues, see Lichtenstein, Fischhoff, and Phillips.

tures price distribution and the distributions of individuals may reflect routine errors in the judgment of individuals and may indicate that the market has a different model for generating price distributions.

Our analysis will compare the subjective price distributions of individuals aggregated in groups to the distributions embodied in the futures and option prices quoted during the same time period. The comparisons will be for both a nearby and a more distant time horizon. The next section of this article describes the method used to elicit and represent the subjective distributions of survey respondents. The methods for generating and comparing statistics that summarize these distributions and the distributions embodied in futures and option prices are then described, followed by the results and concluding comments.

Method for Determining Price Expectations

During the summer and fall of 1987, farmers and grain merchandisers in Illinois were surveyed to obtain their subjective distributions of future corn and soybean prices for dates in the 1987–88 crop year. A total of 237 corn and soybean producers in six groups from 68 of the 102 counties in Illinois were surveyed. Fourteen merchandisers from four counties in east central Illinois were also surveyed. Table 1 lists survey groups, number of respondents, elicitation periods, forecast dates, and the length of each forecast in days. To obtain expectations from a large number of respondents during a brief period, large gatherings of farmers were used as the survey arena. The farmers who participated in the survey were not selected at random but instead volunteered to participate in response to requests for participation. The grain merchandisers were those who responded to randomly generated requests made at visits to elevators in east central Illinois.

Using a technique suggested by Bessler and Moore, survey respondents were asked to provide a distribution of cash corn and soybean prices as well as a distribution of their local basis for each grain, for both a nearby and more distant forecast horizon. Thus, each respondent provided a total of eight subjective distributions. The method used to elicit distributions provides a direct, although restricted, estimation of an individual's subjective probability distribution. Cash and basis price lines were partitioned into eighteen discrete intervals for the summer elicitation periods and sixteen intervals for the fall elicitation periods. Producers and merchandisers were asked to provide price distributions by assigning any number of a total of ten weights to price intervals to indicate how strongly they believed the realized price would fall within an interval. Their confidence in the likelihood was indicated by the number of weights assigned to an interval; i.e., if all ten weights were assigned to an interval, the respondent was indicating 100% confidence that the realized price would fall in that interval. Pilot tests of the survey conducted during the spring of 1987 indicated that respondents were able to complete the survey with greater ease when given an example; thus, an example regarding football scores was given

Table 1. Composition of Survey Groups, Number of Respondents, Elicitation Periods, Forecast Dates, and Forecast Length in Days

Group	Description of Groups	Number of Respondents	Period of Elicitation	Forecast Dates	Forecast Length (Days)
1	Illinois Farm Bureau Meeting; producers selected in exhibit hall.	44	8 Dec. 1987	1 Jan. 1988	23
				1 March 1988	82
2	Illinois Farm Bureau Meeting; producers selected prior to outlook meeting	51	7 Dec. 1987	1 Jan. 1988	24
				1 March 1988	83
3	Relatives of U of I undergraduate students; Thanksgiving vacation	47	25–27 Nov. 1987	1 Jan. 1988	34
				1 March 1988	93
4	Farmers in Farina, Illinois cafe	22	12 Nov. 1987	1 Jan. 1988	49
				1 March 1988	108
5	WILL Radio Outlook meeting; producers selected prior to meeting	59	14–17 July 1987	1 Nov. 1987	108
				1 March 1988	228
6	Elevator merchandisers in east central Illinois	14	14–17 July 1987	1 Nov. 1987	108
				1 March 1988	228
7	Whiteside County, options extension meeting; producers selected prior to meeting.	14	25 June 1987	1 Nov. 1987	128
				1 March 1988	248

on the cover of each survey along with instructions. The pilot tests also indicated that producers did not have difficulty keeping track of the ten weights. No monetary rewards were used to motivate accurate assessments.[3]

To compare the expectations of survey respondents to futures and option prices, cash and basis distributions of survey respondents are combined to obtain a subjective futures price distribution. Respondents were asked to provide subjective probability distributions for cash prices and the local basis rather than directly eliciting their futures distribution. This approach prevented respondents from responding with current futures quotes and minimized the likelihood that respondents would use the current futures quote as an anchor.

A subjective distribution of the logarithm of the futures price was constructed by crop, forecast horizon, and respondent by combining each respondent's cash and basis distributions for a particular crop. The subjective mean for each group was then calculated as follows:[4]

$$\sum_i \sum_j \sum_k p_{ik} p_{jk} \ln(C_{ik} - B_{jk}),$$

where C_{ik} is the cash price represented by interval i for respondent k; B_{jk} is the basis (cash–futures price) represented by interval j for respondent k; p_{ik} is the subjective probability associated with cash interval i for respondent k; and p_{jk} is the subjective probability associated with basis interval j for respondent k.

The cash and basis level used for a particular interval is the interval's midpoint. The summations, i and j, are over the sixteen or eighteen intervals, as appropriate. The summation over respondents, k, in each group differs across groups. All calculations are based on the natural logarithm of $C_{ik} - B_{jk}$ to conform with the assumption of lognormality in the futures price distribution. Each possible value obtained in the summation was assigned a subjective probability based on the sum of $p_{ik}p_{jk}$ for each value (e.g., ignoring logs, if $p_{ik}p_{jk}$ for \$2.00 + \$.20 is .04 and $p_{ik}p_{jk}$ for \$2.10 + \$.10 is .25, then the subjective probability for \$2.20 is .29). This method of combination assumes independence between p_{ik} and p_{jk}, that is, that cash and basis distributions are independent. This assumption was supported by weak correlations between expected mean values of cash prices and expected mean basis values.

Methods for Comparing Price Expectations to Futures and Option Prices

As described above, individual subjective distributions of futures prices were aggregated by summing the probabilities associated with each possible futures price value over individuals surveyed during the same time period. These summed probabilities and respective (log) price values were then used to calculate the moments of the aggregate distributions of expected futures prices. Because the mean and variance completely determine the lognormal distribution, only these moments of the distributions of expected prices are considered.

The subjective variances are represented for each aggregate distribution in two ways. First, because it is easier to think in terms of levels as opposed to the logs, the variance of the ratio P_{t+1}/P_t is reported. Under the assumption that log of this ratio is normally distributed with mean μ and variance σ^2, the variance of the ratio P_{t+1}/P_t is calculated as

$$\text{var}(P_{t+1}/P_t) = \exp(2\mu + \sigma^2)[\exp(\sigma^2) - 1]$$

(Mood, Graybill, and Boes).[5] Here, μ and σ^2 are the mean and variance of each group's subjective distribution of the logarithm of futures prices.

Variances of subjective price distributions are also considered as annualized expected volatilities, or "annualized percentage standard deviations." These values are consistent with the measure of price variability used and reported by industry and academia for option pricing. The variance of daily log price differences yields a variance rate per day and represents the variance expected for tomorrow's price distribution. The time diffusion process underlying the estimate implies that the variance is proportional to time. The variances obtained from survey respondents are for distributions x days away. To annualize their variance, var[ln(P_{t+1}/P_t)] for each aggregated distribution is multiplied by $365/x$. For example, if the variance for a 60-day forecast is .01, then the annualized variance is (365/60).01

[3] A copy of the survey is available from the authors upon request.

[4] The subjective variance for each group was calculated analogously.

[5] This variance is not appropriate for calculation of confidence intervals, which would be asymmetric in this case.

= .061. The square root of this is .246, and the annualized volatility is expressed as 24.6.

Futures prices are assumed to follow a lognormal diffusion process. Numerous random-walk tests on log-price returns of agricultural futures do not provide clear support for or against lognormality (Kamara). Direct tests have often found leptokurtoticity, but these may result from a changing variance over time (e.g., Anderson and Danthine, Cootner, Neftci). Further, the assumption of lognormality is consistent with the Black option pricing model, which is used here to estimate the market's variance forecast.

Under the assumption of lognormality of futures prices, the mean of the distribution expected for the forecast date is the current log futures price. The market's variance forecast is based on implied volatilities of corn and soybean option premiums quoted for the forecast dates for each commodity. Implied volatilities (IVs) were calculated under Black's model for calls with strike prices nearest to but out of the money (the first strike above the relevant futures price). Calls slightly out of the money were used because (*a*) calls are usually traded more than puts, and (*b*) studies indicate that options deep in or out of the money are "mispriced" (wrong implied volatility) more often than those near the money. (See Hauser and Neff for a brief review of some of these studies.)

In addition to the IV based on options traded on the ending date of each elicitation period, an average IV is reported. This is a five-day average based on the IV of the ending date of the elicitation period and the IV from the four preceding trading days. An average IV presumably reduces the effect of possible outliers in the option premia while maintaining an information period comparable to that of the survey respondents.[6]

Differences between the first two moments of the respondents' and markets' distributions are tested. To conduct tests of differences in means and variances, it is assumed that the degrees of freedom associated with the futures price distribution are given by the trading volume of the call option used to calculate the implied volatility. These volumes averaged about 1,000 for the options considered and are, thus, effectively infinite. Hence, the mean and variance of futures are taken as known parameters in the tests. In addition, all tests are conducted with logged values of the data to remain consistent with the lognormality of futures.

Results

The means of the aggregate distributions of survey respondents are reported for each survey group and forecast date in table 2 for both soybeans and corn. Table 2 also reports the settlement futures price quoted during the elicitation period (or average settlement price over the days within a multiday survey period) for each survey group and forecast date. Finally, table 2 presents the differences between the means of the aggregate distributions and the futures settlement prices. The test for significant differences in log means was conducted using the variances obtained from the IVs and averaged IVs under the assumption that these are the "true" parameters. Thus, the test statistic is a standard normal.[7]

Of the fourteen corn price differences between the respondents and the market, five are significantly different than zero at the 5% level (four using the averaged IV to calculate the variance). Only one of the fourteen soybean differences is significant. Four of the six significant differences are from the fall survey period, and fifteen of the sixteen differences for producers in this period are positive, indicating a tendency of farmers to overestimate future price levels relative to the futures market during this period.

None of the subjective means of the grain merchandisers (Group 6) significantly differs from the corresponding futures price. This group likely has greater exposure to market information than would farmers in general; thus, the general agreement of grain merchandisers with the current futures is not surprising. The only group of farmers with no significant disagreement with the current futures is Group 3, the relatives of University of Illinois College of Agriculture undergraduates. Perhaps this group's

[6] The average difference between the averaged IVs and the IVs based on the ending date of the survey period is 9.19% for soybeans and 3.5% for corn. Schmalansee and Trippi suggest that use of an average IV (such as our 5-day average) tends to eliminate the need for Latane and Rendleman's weighting scheme.

[7] The test is a standard normal. The test statistic is

$$Z_{kt} = \frac{\mu_k - \ln(F_t)}{(\sigma_t^2/n_k)^{.5}}$$

where μ_k is the sample mean of the logged responses for group k; $\ln(F_t)$ is the log of current futures for the relevant forecast date; σ_t^2 is the variance of current futures calculated using either the IV or the averaged IV; and n_k is the number of respondents in group k.

Table 2. Means of Aggregate Distributions of Survey Respondents, Settlement Futures Prices Quoted during the Elicitation Period, and Differences between Means of the Aggregate Distributions and the Futures Settlement Price

	Soybeans			Corn		
Group/Forecast	Mean of Aggregate Distribution	Settlement Futures Price	Aggregate Mean–Futures Settlement	Mean of Aggregate Distribution	Settlement Futures Price	Aggregate Mean–Futures Settlement
1 Jan.	5.9206	5.8725	0.0481 (0.2983)	1.9024	1.8639[a]	0.0385 (0.1120)
1 Mar.	6.2266	5.9550	0.2716*[b] (0.0056)	1.9983	1.9100	0.0883 (0.0546)
2 Jan.	5.9061	5.8975	0.0086 (0.4936)	1.9432	1.8722[a]	0.0710* (0.0037)
2 Mar.	6.1071	5.9875	0.1196 (0.1288)	2.0008	1.9175	0.0833 (0.0524)
3 Jan.	6.0185	6.0213	−0.0028 (0.5738)	1.9279	1.9222[a]	0.0057 (0.5649)
3 Mar.	6.1652	6.1050	0.0602 (0.3727)	2.0349	1.9613	0.0736 (0.1576)
4 Jan.	5.6342	5.6150	0.0192 (0.4519)	1.9502	1.8281[a]	0.1221* (0.0011)
4 Mar.	5.7966	5.6900	0.1066 (0.2486)	2.0359	1.8700	0.1659* (0.0032)
5 Nov.	5.2225	5.2675	−0.0450 (0.7818)	1.6882	1.7758[c]	−0.0876* (0.9996)
5 Mar.	5.5215	5.4283	0.0932 (0.2909)	1.8692	1.8658	0.0034 (0.5800)
6 Nov.	5.1001	5.2675	−0.1674 (0.8436)	1.7782	1.7758[c]	0.0024 (0.5212)
6 Mar.	5.4098	5.4283	−0.0185 (0.5404)	1.8994	1.8658	0.0336 (0.3978)
7 Nov.	5.4492	5.5800	−0.1308 (0.7119)	1.8195	1.9925[c]	−0.1730+ (0.9808)
7 Mar.	5.7370	5.7750	−0.0380 (0.5664)	1.9689	2.0650	−0.0961 (0.7554)

Note: Settlement futures prices are those quoted during elicitation period or average settlement price over the days within a multiday survey period.

[a] January futures settle price calculated by: ln *Jan* = ln *Dec* + ($r * s$), where r = (ln *March* − ln *Dec*)/t, where $s = 1/12$, and $t = .25$.

[b] Asterisk indicates significant at the 0.05 level using both the variance based on the IV from the survey day or the 5-day average IV. Values in parentheses are the p-values (1 − CDF) using variances based on the IV from the survey date; cross indicates significant at the 0.05 level using variance based only on the IV from the survey day but not using the variance based on the 5-day average. Significance tests were performed on the logged data.

[c] December futures settle price.

general agreement with the futures market is partly because of the length of time (Thanksgiving vacation) that respondents had to complete the survey. Respondents also may have taken extra care to complete the survey because their children asked for their participation.

Table 3 reports the subjective variances of the aggregate distributions of futures prices both as the variance of the ratio P_{t+1}/P_t, calculated assuming the lognormality of this ratio as described earlier and as annualized expected volatilities for both soybeans and corn. The annualized volatilities implied by the option premia are presented as well.

Although most respondents expected a larger price variance for the March distribution than for the nearby date, all respondents' annualized subjective volatilities are lower for March than for the nearby date. Similarly, the respondents' annualized subjective volatilities are higher for forecasts with shorter time horizons (e.g., December forecasts of March 1) than for longer time horizons (e.g., July forecasts of March 1). The market volatilities implied by option premia are not uniformly smaller for the more distant forecast date.

The annualized volatility estimates derived for the market as well as the respondents represent an average variance rate. If the variance rate is constant over the forecast period, then the average equals this constant rate. However, the actual variance rate may change over time, and the time period length over which a given rate level exists may change. For most option pricing models, including Black's, the theoretical solution can be based on any variance rate which is a continuous function of time (and/or underlying commodity price). For corn and soybean prices, fairly strong evidence of seasonality in variance rate has been found (Anderson, Hauser and Andersen, Kenyon et al.). At a point in time, if the longer horizon's annualized volatility is larger/smaller than the shorter horizon's, the simple average of the variance rate for the more distant horizon will also be greater/less than for the shorter horizon. The inverse relationshp in table 3 between forecast horizon and the respondents' annualized volatility suggests a perception of a decreasing variance rate over time.

Table 4 reports the results of chi-square tests of the ratios of the variances expected by the survey respondents to the variances implied by

Table 3. Variances of the Aggregate Distributions of Expected Futures Prices of Survey Respondents and Annualized Volatilities Implied by Option Premia

	Soybeans				Corn			
			Annualized Volatilies Implied by Option Premia				Annualized Volatilities Implied by Option Premia	
Group and Forecast	Survey Var (P_{t+1}/P_t)	Annualized Expected Volatility	Survey Date	5-Day Average	Survey Var (P_{t+1}/P_t)	Annualized Expected Volatility	Survey Date	5-Day Average
1 Jan.	0.1028	21.56	33.4	30.1	0.0280	34.98	36.0[b]	35.9[b]
1 Mar.	0.1576	13.44	23.5	26.9	0.0322	18.92	36.0	35.9
2 Jan.	0.0879	19.57	34.4	30.1	0.0280	33.54	34.9[b]	36.4[b]
2 Mar.	0.1048	11.11	24.3	27.8	0.0381	20.42	34.9	36.4
3 Jan.	0.1614	21.85	32.4	29.8	0.0427	35.04	37.8[b]	36.5[b]
3 Mar.	0.2397	15.71	27.9	27.0	0.0740	26.37	37.8	36.5
4 Jan.	0.0879	14.35	21.5	22.3	0.0257	22.41	25.7[b]	23.9[b]
4 Mar.	0.0890	9.45	21.9	22.0	0.0319	16.11	25.7	23.9
5 Nov.	0.2795	18.56	24.8[a]	27.6[a]	0.0503	24.32	25.0[c]	25.6[c]
5 Mar.	0.1818	9.76	24.8	27.6	0.0502	15.12	25.5	25.5
6 Nov.	0.2143	16.65	24.8[a]	27.6[a]	0.0208	14.89	25.0[c]	25.6[c]
6 Mar.	0.1116	7.80	24.8	27.6	0.0284	11.20	25.5	25.5
7 Nov.	0.1728	12.86	30.1[a]	32.3[a]	0.0810	26.25	31.4[c]	33.9[c]
7 Mar.	0.2965	11.49	30.1	32.3	0.0585	14.85	36.2	37.3

[a] Because premia for the March option were not available during this time period, these annualized volatilities are based on the November option premia.
[b] Because January corn options do not exist, volatilities based on the March corn option are used for the January annualized volatilities.
[c] December corn options used to calculate November volatilities.

option premia. This test was used to test for differences between the survey and market variances. The chi-square tests were performed by converting annualized percentage standard deviations to variances.[8]

The subjective variance of survey respondents for soybeans is always significantly less than the implied variance, except for the near forecasts of the grain merchandisers with respect to the option premium of the survey date. For corn, subjective variances for near forecasts are not significantly different than implied variances for any group except the grain merchandisers. For the distant forecast, subjective variances for corn are all significantly less than implied variances.

Under many paradigms for measuring behavior under risk, these findings imply that respondents perceive a lower level of risk in soybean prices and in distant corn prices than does the market. This suggests that the IV as an estimate of the subjective variance (risk) is biased upward.

For corn, the greater agreement between survey and market near-horizon forecasts of variance is consistent with past studies that have found a high correlation between IVs and recently observed variance, or historical variance (e.g., Hauser and Andersen, Kenyon et al.). To the extent that the IV is a function of historical variance, the present analysis suggests that the respondents believe current volatility conditions will persist in the near term for corn but not in the long term.

Hauser and Eales provide a perspective on how the commodity hedger's subjective variance relative to the market's IV affects the risk and return of the hedging strategies as perceived by the hedger. In their framework, the results of table 4 suggest that the respondents believe the soybean options and distant corn options are overpriced. In these cases, producers would be reluctant to hedge through purchase of puts, though the sale of calls may be attractive.

[8] The test is chi-squared with degrees of freedom equal to the number of respondents. The test statistic is

$$X_{kt} = \frac{\sigma_k^2 n_k}{\sigma_t^2},$$

where: σ_k^2 is the variance of logged survey responses for group k; σ_t^2 is the variance of logged futures based on either IV or the averaged IV; n_k is the number of respondents in group k.

Table 4. Chi-Square Statistics from Tests of the Ratios of the Variances Expected by Survey Respondents to the Variances Implied by Option Premia

Group and Forecast	Soybeans Survey Date	Soybeans Five-Day Average	Soybeans Degrees of Freedom	Corn Survey Date	Corn Five-Day Average	Corn Degrees of Freedom
1 Jan.	14.16*[a]	17.44*	34	33.98	34.17	36
1 Mar.	10.79*	8.23*	33	9.66*	9.72*	35
2 Jan.	14.56*	19.02*	45	42.48	39.05	46
2 Mar.	9.40*	7.18*	45	15.40*	14.16*	45
3 Jan.	19.55*	23.11*	43	36.94	39.62	43
3 Mar.	13.31*	14.21*	42	20.92*	22.44*	43
4 Jan.	7.57	7.04*	17	12.92	14.94	17
4 Mar.	3.17*	3.14*	17	6.68*	7.72	17
5 Nov.	28.57*	23.07*	51	47.30	45.11	50
5 Mar.	7.74*	6.25*	50	17.92*	17.92*	51
6 Nov.	5.41	4.37*	12	4.26*	4.06*	12
6 Mar.	1.19*	0.96*	12	2.31*	2.31*	12
7 Nov.	2.01*	1.74*	11	9.09	7.80	13
7 Mar.	1.60*	1.39*	11	2.19*	2.06*	13

[a] Asterisk indicates significant at the 0.05 level. Note that since, a priori, either variance may be larger, the test is two-tailed.

Conclusions

The means of twenty-two of the twenty-eight survey distributions are not significantly different than the futures price. Of the six significant differences, four are significantly greater than the futures price. However, all four are from the same time period and probably indicate a disagreement between respondents and the futures market peculiar to that period rather than a systematic bias in the relationship between futures prices and individual expectations. For two groups, no significant difference occurred between the futures price and group means. The composition of these two groups suggests that agreement with the futures market is more likely the longer is the time given to express expectations and the greater is the familiarity with the prices quoted on futures markets.

There is strong evidence of systematic disagreement between the respondents and market with respect to variance forecasts. The differences between survey and market variance expectations always imply that the respondents (both farmers and grain merchandisers) expect a lower variance than the market.

Any lack of significant disagreement between futures prices and means of the subjective price distributions may occur because farmers and grain merchandisers consider the futures market when forming price expectations. Our results may have occurred because the futures price is readily observable, while IVs are not. This explanation is consistent with the finding that the subjective means of those people with more time and greater exposure to futures were most likely to agree with futures prices.

These findings suggest that in most instances the futures price is an appropriate proxy for expected price. However, market IVs do not appear to reflect accurately the subjective variances of producers and merchandisers. The difference between the survey and market variances imply (*a*) IVs are overestimates of variance perceptions; (*b*) an important factor determining the type and extent of hedging with options, futures, and other risk management tools may be the difference in perceived variances; and (*c*) observations about producer's risk aversion should consider these differences in perceived variances. Finally, the difference between survey and market price distributions is consistent with the phenomenon of overconfidence reported in psychology literature.

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Imperfect Competition in Agricultural Markets and the Role of Cooperatives: A Spatial Analysis

Richard J. Sexton

Important characteristics of many agricultural markets are costly to transport raw products and relatively few processors, one or more of which is often a cooperative. This paper analyzes pricing behavior in these oligopsonistic, spatial markets and focuses specifically upon the conjecture that cooperatives may have a procompetitive effect on the behavior of rival non-co-op processors. The existence and magnitude of a procompetitive effect is shown to depend upon a number of structural and strategic factors including competitive relations among the non-co-op processors and a cooperative's membership and pricing policies.

Key words: agricultural markets, conjectural variation, cooperatives, imperfect competition, oligopsony, spatial markets.

In a typical agricultural market, raw product production is by a large number of spatially dispersed farmers who act as price takers. The raw product is bulky and/or perishable and, thus, costly to transport. Processing of the raw product is by a relatively few marketing firms, and one or more of the processors is a cooperative.[1]

The first three of these conditions jointly suggest that processors may exercise spatial oligopsony power over farmers, but the classic works on farm–retail price spreads (George and King, Gardner) have assumed nonspatial perfect competition or, in the case of Bressler and King, recognized the spatial dimension but for the most part failed to deal with the attendant implications for firm behavior. Previous analysis that have examined spatial market power [e.g., Capozza and Van Order (CVO) and Greenhut, Norman, and Hung (GNH)] have focused on seller market power in retail markets.

The trend toward fewer and larger processing facilities makes the spatial dimension of agricultural markets increasingly important over time. Given the concern about oligopsony power in these markets, an interesting question that provides the focus of this paper is the role cooperatives may play in mitigating the potentially adverse performance implications of structural oligopsony. The notion that a cooperative may have a salutary effect on its rivals' behavior is known as the "yardstick of competition" hypothesis. The merit of this hypothesis is crucial to understanding the implications of alternative market structures, measuring cooperatives' market performance, and evaluating the public policy implications of cooperatives, but, surprisingly, the topic has received little formal attention. Apart from Fulton's recent analysis of the Canadian fertilizer industry, studies of agricultural markets have not distinguished cooperatives from other marketing firms.[2] Moreover, analyses of marketing cooperatives have usually examined the cooperative in isolation as if it were a monopsony processor.[3] The industry norm, though, is that cooperatives coexist with other firms in markets that are structural oligopolies or oligopsonies (Cotterill, Fulton). For exam-

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[1] Cooperatives aggregate market share in the United States measured at the farm gate is roughly 30%. The share is significant, moreover, across several industry groups, including dairy, 77%; cotton, 36%; grain and soybeans, 36%; fruits and vegetables, 20%; and livestock, 11% (Wissman). Cooperatives are also important market forces in many European and developing-country economies.

[2] For example, Just and Chern concluded that the California tomato-processing market exhibited oligopsonistic behavior but failed to consider that the market contains two cooperative processors and a cooperative bargaining association.

[3] See surveys of this literature by LeVay, Sexton, and also Staatz.

ple, raw product markets that generally satisfy these structural conditions include dairy, cotton, some grains, and many processing fruits and vegetables. A partial listing here would include apples, avocados, citrus, olives, peaches, pears, potatoes, and tomatoes.[4]

The goal of this paper is to characterize formally the pricing behavior of for-profit processors (i.e., processors that are not cooperatives) in these oligopsonistic spatial markets in the absence and presence of cooperative processors. These results are derived from a conjectural variations model of oligopsony competition in which the key consideration is the for-profit processor's rational conjecture of a cooperative's behavior in contrast to the conjectures it might plausibly entertain for the behavior of a rival for-profit processor.

In this manner we are able to derive and compare equilibrium processor-farm price spreads under alternative market structures and modes of co-op behavior. In so doing, this analysis establishes formally the conditions for which a yardstick effect does and does not exist, and develops conceptual measures of the magnitude and determinants of the effect.

The paper proceeds in the next section to develop a model of spatial competition in the marketing sector wherein the effect of alternative forms of competition on the farm-processor price spread is demonstrated. The analysis is then broadened to include cooperatives among the set of processors. The effect of cooperatives on noncooperatives' price spreads is demonstrated for alternative modes of cooperative behavior. The paper concludes by exploring implications of the results for antitrust policy and public policy towards cooperatives and by suggesting further research.

Spatial Competition in Agricultural Markets

This section derives the farm–processor price spread under alternative modes of spatial competition. These results are compared in the next section to price spreads for markets in which a cooperative is present. To simplify the analysis, it is assumed that processors are homogenous and are price takers in their selling markets. The analysis is easily extended, however, to handle imperfect competition in the selling markets (see footnote 7). Farmers are also assumed to be homogenous and distributed uniformly in space with density D.

An individual farmer's supply curve is denoted as

$$r_i = r_i(W_i),$$

$r_i' > 0$, where r_i is the quantity of raw product supplied and W_i is the net price received by the farmer. In turn, $W_i = w - tL_i$, where w is the mill price offered by the processor, t is the cost to transfer a unit of the raw product one unit of distance, and L_i is the farm-to-processor distance. Transfer costs are assumed to be borne by the farmer, although this point is not essential to the analysis. Thus a higher mill price calls forth an increased supply from each farmer.

In modeling supply to a processor, we follow conventional spatial theory and assume that competition occurs in n directions. Given homogeneity in technology and behavior among processors, a given firm's market radius will be identical in each direction and denoted by L. The representative processor's supply, R, is then

$$(1) \quad R(W, L) = nD \int_0^L r(W)d\tau, \; W = w - t\tau.$$

The purposes of this paper, it is convenient to rewrite the supply function to a processor in the following general inverse form,

$$(1') \quad w = w(R, L).$$

To further simplify the subsequent analysis, it is assumed that all processors produce a single product q and employ the same quasi-fixed proportions technology wherein no substitution is possible between the raw product and the vector of processing inputs $X = \{x_1, \ldots, x_n\}$, but substitution among the various x_k may be possible.[5] This technology may be written as

$$(2) \quad q = \min \{R/\lambda, h(X)\},$$

where $\lambda \le R/q$ indicates conversion possibilities between raw and processed product, and $h(X)$ is concave with positive and declining marginal products and continuous second derivatives. Given positive prices for R and X, cost minimization requires that $q = R/\lambda = h(X)$. In ad-

[4] Although this paper focuses on raw product markets, analogous concepts are applicable in farm input markets whenever spatial considerations are important as, for example, with bulky inputs such as fertilizer (Fulton) and petroleum.

[5] Dunn and Heien, for example, were unable to reject statistically the hypothesis that elasticities of substitution between farm and nonfarm inputs were zero.

dition to the costs associated with R and X, each processor must incur a fixed set up cost $f > 0$.

Given these conditions on technology, the processor cost function is

$$(3)\qquad c(q) = \begin{cases} 0 \text{ if } q = 0, \\ \lambda wq + m(q) + f, \text{ if } q > 0, \end{cases}$$

where λwq are raw product costs, and $m(q)$ are costs due to the processing inputs, where it follows that $0 < m' < \infty$, $m'' \geq 0$.

Equation (3) embodies economies of size over at least some range for $q > 0$. That is, the effect of spreading $f > 0$ over increasing outputs causes average cost to fall over some $q > 0$ even if $m'' > 0$. Economies of size in processing are necessary to generate a spatial distribution of processors rather than having a processor located at each farm site.

Without loss of generality, let product quantities be measured so that $\lambda = 1$ and $q = R$. Profits for a representative processor producing $q > 0$ are then

$$(4)\qquad Y = PR - m(R) - wR - f.$$

The first-order condition for maximization of (4) is

$$(5)\qquad dY/dR = P - m' - w - R(dw/dR) = 0.$$

To simplify notation, define $p = P - m'$ as the processed product price net of marginal non-raw product processing costs. If $m'' = 0$ as is typically assumed in spatial theory, p is a constant. If $m'' > 0$, p decreases in R.

From (1′) the term dw/dR in (5) can be written as

$$(6)\qquad dw/dR = \partial w/\partial R + (\partial w/\partial L)dL/dR.$$

The term $\partial w/\partial L$ in (6) can be reexpressed through use of the implicit function theorem on (1):

$$(7)\qquad \partial w/\partial L = -(\partial R/\partial L)/(\partial R/\partial w) < 0.$$

The inequality in (7) follows because both $\partial R/\partial L$ and $\partial R/\partial w$ are positive. That is, a higher mill price and a larger market area each call forth a greater raw product volume to the processor. The sign in (7) reflects that larger market areas diminish spatial competition among rival processors, increasing the monopsony power of a given firm and, thus, diminishing price.

Interpreting (6) in words, $\partial w/\partial R > 0$ measures the effect on a processor's price from increasing purchases within a given market radius. The magnitude of $\partial w/\partial R$ is determined from growers' supply curves. If, however, the processor believes he can expand market area, L, by raising R and, indirectly, w, then, given $\partial w/\partial L < 0$, it follows that the full price response, dw/dR, is less than the response predicted from examining only $\partial w/\partial R$. In other words, the greater is dL/dR the less flexible (more elastic) is the total raw product supply response facing the processor.

Converting (6) to elasticities obtains;

$$(8)\qquad \eta_{w,R} = \epsilon_{w,R} + \epsilon_{w,L} \cdot \eta_{L,R'}$$

where $\eta_{w,R} = (dw/dR)(R/w)$ is the total price flexibility of w (inverse elasticity of R), $\epsilon_{w,R} = (\partial w/\partial R)(R/w)$ is the corresponding partial flexibility (inverse elasticity), $\epsilon_{w,L} = (\partial w/\partial L(L/w)$, and $\eta_{L,R} = (dL/dR)(R/L)$. Substituting (8) into (5) obtains

$$(9)\qquad \frac{p - w}{w} = \epsilon_{w,R} + \epsilon_{w,L} \cdot \eta_{L,R}.$$

That is, the relative farm–processor price spread is determined by the raw product supply flexibility facing the firm and by the product of the flexibility of the mill price w with respect to market dimension L and the elasticity of L with respect to the quantity of the raw product purchased.

Examining the individual terms in (9), larger $\epsilon_{w,R}$ means a more flexible (less elastic) raw product supply and a larger price spread, *ceteris paribus*. As noted in (7), the term $\epsilon_{w,L} < 0$ measures the competitive effect of larger market areas. Its effect on the price spread is determined jointly with $\eta_{L,R}$, the key term for purposes of this paper.

$\eta_{L,R}$ is the spatial competition analog of the classical conjectural variation. It measures the processor's perception of competitive conditions in the market. For example, increasing R implies increasing w as a necessary condition to call forth greater raw product supply given $r_i' > 0$. How rapidly w increases depends on the extent to which the processor can attract supply from rival processors. That is, it depends on the magnitude of dL/dR. If the firm believes dL/dR is small or even zero, competitive behavior to raise R is less profitable than if dL/dR is large because w will rise relatively rapidly. For example, if $dL/dR = 0$, any increase in R must be generated solely from the growers in the area defined by L, and price must rise in accord with their aggregate supply flexibility. Small dL/dR

is equivalent to a perceived aggressive response from rivals attempting to preserve their market area. Such a perception discourages the firm from behaving competitively. Monopsony pricing and high margins are then the outcome.

Two alternative behavioral postulates have received primacy in spatial theory (CVO, GNH): Loschian competition, wherein each competitor behaves as if his market area is fixed, and Hotelling-Smithies competition, wherein each competitor believes his actions will not affect his rivals' prices. The Hotelling-Smithies conjecture is the Nash conjecture in a price-setting context, but an alternative conjecture, owing to Cournot, that a given firm's quantity changes will go unheeded by rivals, is the Nash conjecture in this quantity-setting model.

To elucidate the behavior implications of these alternative conjectures, note that equilibrium behavior (assuming all markets are served) requires the net prices of rivals to be equal at their common borders. Letting u_j denote the arc distance between a representative firm and its jth rival, $j = 1, \ldots, n$, and w_j, the jth rival firm's price, the equation defining the market boundary L_j between the two firms is

$$(10)\qquad w - tL_j = w_j - t(u_j - L_j), j = 1, \ldots, n.$$

Given symmetric rivals, let $u_k = u_j = u$, $w_k = w_j = \bar{w}$, and $L_k = L_j = L$. The market boundary is then symmetric in all n directions ($\bar{w}$, $\bar{R}$, are, henceforth used to denote a rival's price and output while w, R denotes the representative processor's price and output). Note that fixed u implies that plant locations and numbers are fixed, a condition equivalent to the usual oligopoly/oligopsony condition that number of firms in the market is fixed in the short run. Moreover, the market boundaries, L, are also known and treated as fixed in the short run with the crux of the subsequent analysis focusing on firms' perceptions of how their behavior will affect the market boundaries. Solving (10) for $L_j = L$ and differentiating obtains

$$(11)\qquad \frac{dL}{dR} = \left[\frac{dw}{dR} - \frac{d\bar{w}}{dR}\right]\frac{1}{2t}.$$

The Loschian conjecture is that $dL/dR = 0$. From (11), it implies $d\bar{w}/dw = 1$, any price change generated by the representative firm's behavior will be exactly matched by its rival. This is the collusive conjecture in nonspatial oligopsony theory and leads to the joint monopsony solution when all firms entertain this conjecture.[6] Loschian (LO) competition is, therefore, the spatial analog to collusive behavior in a nonspatial context, and from (9)

$$(9')\qquad \left(\frac{p - w}{w}\right)^{LO} = \epsilon_{w,R}.$$

The Hotelling-Smithies (H-S) conjecture is $d\bar{w}/dw = d\bar{w}/dR = 0$. Its nonspatial analog is Bertrand competition, which is known to generate the competitive solution where price equals marginal cost whenever markets have homogenous products and firms with nonbinding capacity constraints. Substituting (11) into (6) with $d\bar{w}/dR$ set equal to zero obtains

$$(12)\qquad \frac{dw}{dR} = \frac{\partial w/\partial R}{1 - (1/2t)\partial w/\partial L}.$$

Substituting (12) into (5) and rearranging as indicated in (9) gives the price spread when all rivals engage in Hotelling-Smithies competition:

$$(9'')\qquad \left(\frac{p - w}{w}\right)^{H\text{-}S} = \epsilon_{w,R}\left[\frac{1}{1 - (1/2t)(\partial w/\partial L)}\right].$$

Given $\partial w/\partial L < 0$ from (7) and $m'' \geq 0$, it follows from (9″) that *H-S* competition induces higher w and a lower price spread than Loschian competition, a result consistent with their respective analogs in nonspatial imperfect competition.

The Cournot-Nash (*C-N*) conjecture is $d\bar{R}/dR = 0$. Denoting the raw product supply facing a rival as $\bar{w} = \bar{w}(\bar{R}, u - L)$ and differentiating obtains

$$(13)\qquad \frac{d\bar{w}}{dR} = \frac{\partial \bar{w}}{\partial L}\frac{dL}{dR}$$

upon invoking the $d\bar{R}/dR = 0$ conjecture.

Given that processing firms are symmetric, it follows in equilibrium that

$$(14)\qquad \partial \bar{w}/\partial L = -\partial w/\partial L.$$

That is, each unit increase in L induces a unit decrease in $(u - L)$, a rival's radius. Therefore, a change in L will have an effect on w exactly opposite of its effect on $\bar{w}$. In particular, note that $\bar{R}/dR = 0$ implies $d\bar{w}/dR > 0$. That is, as $u - L$ shrinks in response to $dR > 0$, the rival

[6] Given that marginal costs are the same for all processors, the conjectures must be the same across firms in equilibrium (Appelbaum).

must raise price to call forth a constant supply from its diminished market area.

Substituting (13) and (14) into (11) and rearranging obtains

$$(11') \quad \left(\frac{dL}{dR}\right)^{C\text{-}N} = \frac{dw}{dR}\left[\frac{1}{2t - \partial w/\partial L}\right].$$

Substituting (11′) into (6) for dL/dR and then converting to the relative price spread as illustrated previously obtains

$$(9''') \quad \left(\frac{p - w}{w}\right)^{C\text{-}N} = \epsilon_{w,R}\left[\frac{2t - (\partial w/\partial L)}{2t - 2(\partial w/\partial L)}\right].$$

Comparing (9′), (9″), and (9‴), it is easy to show that

$$\left(\frac{p - w}{w}\right)^{LO} > \left(\frac{p - w}{w}\right)^{C\text{-}N} > \left(\frac{p - w}{w}\right)^{H\text{-}S}.$$

The preceding approach can be generalized by noting that the alternative conjectures can all be written in terms of dw/dR:

$$\text{Loschian: } dL/dR = (0)dw/dR;$$

$$H\text{-}S\text{: } dL/dR = (1/2t)(dw/dR);$$

$$C\text{-}N\text{: } dL/dR = (dw/dR)/(2t - \partial w/\partial L).$$

Thus, letting $dL/dR = \theta dw/dR$, we obtain from (6) and (9) the following general formulation of the price spread:

$$(15) \quad \frac{p - w}{w} = \epsilon_{w,R}\left[\frac{1}{1 - \theta(\partial w/\partial L)}\right].$$

From (15) $d((p - w)/w)/d\theta < 0$. That is, the greater the dL/dR conjecture, the higher is w and the lower the price spread for the reasons given earlier. If $m'' > 0$, rising incremental processing costs reinforce the effect of θ on margin behavior.

Note also that θ can be interpreted as an index of market structure ranging from 0 (collusion) to $1/2t$(H-S). From (9″) as $t \rightarrow 0$, $((p - w)/w) \rightarrow 0$ under H-S competition, affirming the equivalency of the H-S and Bertrand equilibria in the nonspatial world. Econometric estimates for θ may be used to test specific hypotheses about market structure (Appelbaum, Karp and Perloff).

The preceding results are summarized geometrically in figure 1, where $P - m'$ denotes the net marginal revenue product (*NMRP*) curve for R. (The curve labelled *NARP* in figure 1 is relevant to discussion of the co-op processor and is defined in the next section.) *NMRP* is the demand curve for the raw product for processors who are competitive in their selling market. Given the raw product supply curve $w(R, L)$ the price-quantity equilibrium is (w^{PC}, R^{PC}) if a processor behaves competitively in the raw product market as well.

However, profit-maximizing processors with spatial market power do not set $w = NMRP$ but, rather, equate *NMRP* with their perceived marginal cost of procuring the raw product. The Loschian, *H-S*, and *C-N* equilibria illustrated in the figure are each based upon different perceptions of this marginal cost function based, in turn, on firms' perceptions of how rivals would react to their changes in w and R.

The Effect of Cooperatives on Farm–Processor Price Spreads

Some concepts from the economic theory of cooperatives need to be introduced initially. The net average revenue product (*NARP*) of the raw product R is the revenue from processed product sales less processing costs, both divided by the quantity of raw product employed. Given $\lambda = 1$ and the processing technology set forth in (2) and (3):

$$(16) \quad NARP = [PR^c - m(R^c) - f]/R^c = P - AC(R^c),$$

where R^c is the cooperative's volume of raw product purchases as well as its output and $AC(R^c)$ is its average cost function for processing inputs.

As noted, the *NMRP* of R is the incremental contribution to net revenue of each successive unit of R employed:

$$(17) \quad NMRP = d[PR^c - m(R^c) - f]/dR^c = P - m'.$$

If $m'' > 0$, *NARP* has the usual inverted "*U*" shape illustrated in figure 1.[7]

Treating the raw product supply curve of its

[7] Another factor which will tend to create an inverted U-shaped *NARP* curve whenever $f > 0$ is the perception by the cooperative that it has market power in the sale of its processed products. The analysis of price spreads in this paper can easily accommodate these market conditions. For example, let $\Sigma^n q_i = Q$ and $P(Q)$, $P' < 0$, denote market demand for the homogenous product Q. Then $dP(Q)/dq_i = P + P'dQ/dq_i$, where dQ/dq_i is the ith firm's conjecture of its effect on total market output. The term $P'dQ/dq_i$ can be converted to elasticities and would appear on the right-hand side of the relative price spread formulations such as (9), with larger dQ/dq_i raising the price spread.

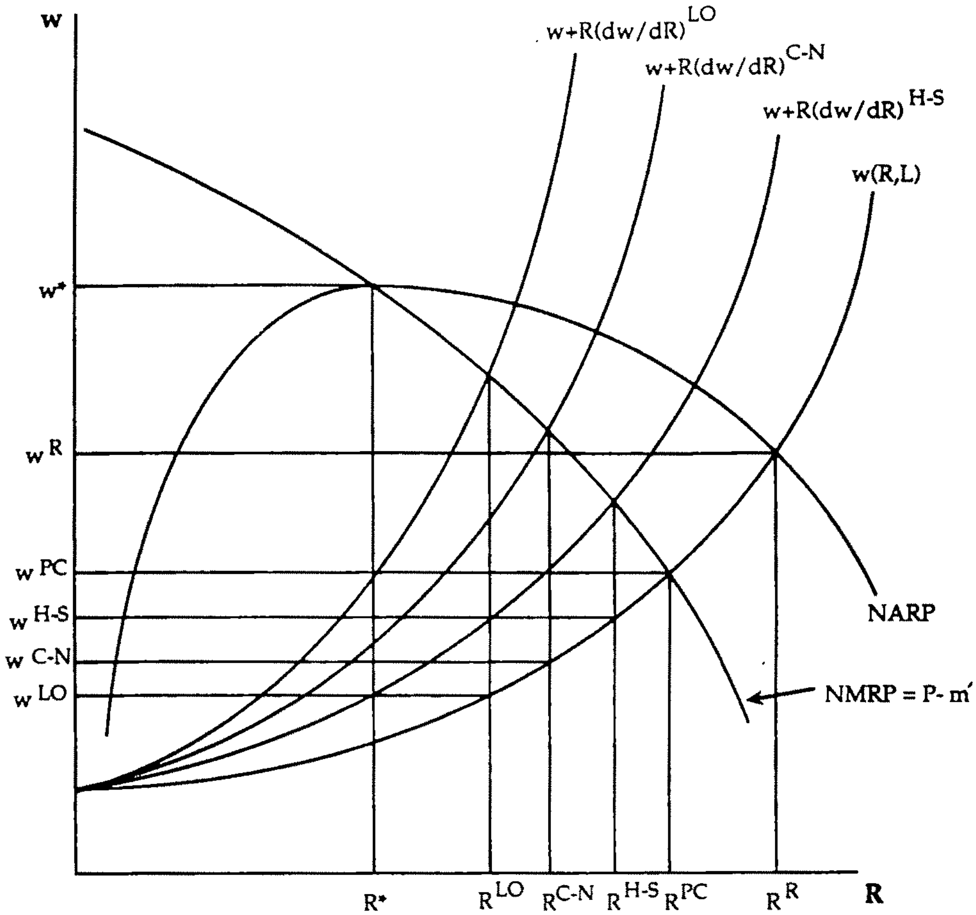

Figure 1. Price–quality equilibria for a for-profit processor and a co-op processor under alternative forms of spatial competition

members as given, it is well known that a cooperative maximizes its members' profit from jointly producing and marketing their product by setting raw product price, w^c, and purchasing quantity, R^c, where *NMRP* intersects member supply.[8] This behavior generates the competitive outcome (w^{PC}, R^{PC}) from figure 1. A problem is that the *NMRP* solution fails to satisfy the constraint that a cooperative break even unless member supply intersects *NARP* at its maximum where *NARP* = *NMRP*. Deficits or surpluses from *NMRP* pricing must be allocated to members as fixed charges or rebates, otherwise members will adjust their quantity supplied from the optimum level (LeVay, Staatz).[9]

The solution that maximizes members' profit subject to setting w^c to breakeven results from setting w^c at the intersection of member supply and *NARP*. As such *NARP* pricing is a Ramsey, second-best optimum—it maximizes member profit subject to the breakeven constraint. The Ramsey solution is denoted as (w^R, R^R) in figure 1.

The extent to which a cooperative plays a pro-

[8] Issues pertaining to the traditional price-output equilibrium have been extensively analyzed and debated. Summaries of the discourse are provided in survey papers by LaVay, Sexton, and also Staatz.

[9] Examples of fixed charges/rebates would be a lump sum levy or rebate per member or an allocation based on a fixed input such as acreage. Allocations, that can be linked back to patronage, e.g., patronage refunds, do not work in this regard because members rationally inpute the refund or levy as part of their net price and adjust their supply behavior accordingly. The ensuing equilibrium is not (w^{PC}, R^{PC}) but, rather, (w^R, R^R).

competitive role in an oligopsonistic market is shown here to depend on whether the cooperative (*a*) has an open or closed membership policy,[10] (*b*) is operating in the upward or downward sloping portion of *NARP*, and (*c*) sets price according to *NMRP* or *NARP*.

In considering these alternative scenarios, note that whenever a cooperative's *NARP* function is increasing over the range of growers' desired raw product supply, open membership is its optimal policy because adding new members makes existing members better off by raising *NARP*.

Restricted membership becomes an issue for a cooperative when its *NARP* declines within the range of desired grower supply. Some authors have argued that a cooperative will restrict membership and purchase only the quantity of raw product, R^*, that maximizes *NARP*, in which case members can be paid $w^* = NARP(R^*)$, the maximum per unit price possible. Others have argued that the cooperative will maintain open membership and expand purchases into the range of diminishing *NARP*, setting raw product price where growers' supply intersects either *NMRP* or *NARP*. See the references in footnote 8 for further discussion and figure 1 for an illustration of the alternative outcomes.

Our approach is to recognize that each of these scenarios may be descriptive of co-op behavior in various situations and to analyze each in turn. For ease of exposition, price spread behavior for a for-profit processor is derived in the ensuing subsections for the case when the processor faces only co-op rivals. Generalization is subsequently made to the typical real-world case involving both co-op and non-co-op competitors.

The Open Membership Cooperative

An open membership cooperative will attract members until at the market boundary L a grower's payoff as a co-op member equals his payoff from patronizing the neighboring firm—assumed to be a for-profit processor. For the cooperative that sets price according to $w^c = NARP$ and is located distance u from the representative for-profit processor, the boundary condition is simply

$$(10') \qquad w - tL = w^c - t(u - L).$$

Adapting from (11), we have

$$(11'') \qquad \frac{dL}{dR} = \left[\frac{dw}{dR} - \frac{dw^c}{dR}\right] \Big/ 2t.$$

From (16), we obtain

$$(18) \qquad \frac{dw^c}{dR} = \frac{dNARP}{dR^c}\frac{dR^c}{dR} = \frac{dR^c}{dR}\frac{1}{R^c}[AC - m'],$$

where *NARP* is increasing when $AC > m'$, decreasing when $AC < m'$, and a maximum when $AC = m'$. Noting that

$$(19) \qquad \frac{dR^c}{dR} = \frac{\partial R^c}{\partial w^c}\frac{dw^c}{dR} + \frac{\partial R^c}{\partial L}\frac{dL}{dR},$$

and using this result to substitute for dR^c/dR in (18) obtains

$$(18') \qquad \frac{dw^c}{dR} = \frac{(\partial R^c/\partial L)(dL/dR)(AC - m')}{R^c - (\partial R^c/\partial w^c)(AC - m')}.$$

Then substituting (18′) into (11″) obtains

$$(20) \qquad \frac{dL}{dR} = \frac{1}{2t}\frac{dw}{dR} \cdot \left\{\frac{R^c - (\partial R^c/\partial w^c)(AC - m')}{R^c - [\partial R^c/\partial w^c - (\partial R^c/\partial L)/2t](AC - m')}\right\},$$

or

$$(20') \qquad \left(\frac{dL}{dR}\right)^{OM} = \frac{\gamma}{2t}\frac{dw}{dR},$$

as the rational conjecture for a processor facing an open membership (*OM*), *NARP*-pricing cooperative, where γ is the term in curly brackets in (20).

Notice that (20′) embodies the cooperative's Ramsey optimal price response to dR in the sense that adjusting price in accord with *NARP* maximizes the cooperative members' welfare subject to satisfying the breakeven constraint. As such, the conjecture of the for-profit firm in (20) is a rational or consistent conjecture because it embodies a response that is optimal for the cooperative. (See, for example, Jacquemin, pp. 62–65 for a discussion of the concept of consistent conjectures in oligopoly theory.) Because $\partial R^c/\partial L < 0$ in the denominator of γ, it follows that

(21) $\gamma > 1$ when *NARP* is increasing

$\gamma = 1$ when *NARP* is a maximum

$0 < \gamma < 1$ when *NARP* is decreasing.

[10] Youde presented survey evidence to indicate that about three-fourths of "leading" marketing cooperatives and nearly 90% of all others have open membership policies.

Substituting (20′) into (6) for dL/dR and converting to the price spread as in (9) obtains

$$(22)\quad \left(\frac{p-w}{w}\right)^{OM} = \epsilon_{w,R}\left[\frac{1}{1-(\gamma/2t)\partial w/\partial L}\right].$$

The relative competitive effect of the *NARP*-pricing open membership co-op depends upon whether *NARP* is increasing, decreasing, or a maximum at the co-op's output level, R^c.

PROPOSITION 1. *The following relationships summarize the price spreads for a for-profit firm who competes only with open membership (OM) cooperatives versus only with technologically equivalent for-profit rivals conjectured to behave in either a Loschian (LO), Hotelling-Smithies (H-S), or Cournot-Nash (C-N) manner:*

a. Increasing NARP:

$$(23a)\quad \left(\frac{p-w}{w}\right)^{LO} > \left(\frac{p-w}{w}\right)^{C\text{-}N} > \left(\frac{p-w}{w}\right)^{H\text{-}S} > \left(\frac{p-w}{w}\right)^{OM}.$$

b. Maximum NARP:

$$(23b)\quad \left(\frac{p-w}{w}\right)^{H\text{-}S} = \left(\frac{p-w}{w}\right)^{OM}.$$

c. Decreasing NARP:

$$(23c)\quad \left(\frac{p-w}{w}\right)^{LO} > \left(\frac{p-w}{w}\right)^{C\text{-}N} > \left(\frac{p-w}{w}\right)^{OM} > \left(\frac{p-w}{w}\right)^{H\text{-}S}.$$

Proof. Most of the proposition is proved simply by comparing the alternative price spread equations in (9′), (9″), (9‴), and (22). Part (*a*) follows because from (21), $\gamma > 1$. The part (*b*) equality is apparent once $\gamma = 1$ is substituted into (22). For part (*c*), $((p-w)/w)^{OM} > ((p-w)/w)^{H\text{-}S}$ follows from substituting $\gamma < 1$ into (22). The other component of part (*c*), that $((p-w)/w)^{C\text{-}N} > ((p-w)/w)^{OM}$, is verified by noting that the Cournot conjecture, $d\bar{R}/dR = 0$ implies that the rival firm acts as if it has a perfectly inelastic raw product demand curve. That is, in response to $dR \geq 0$, the Cournot rival reacts by raising $\bar{w}$ sufficiently to hold $\bar{R}$ constant. *NARP* plays the role of raw product demand for the *NARP*-pricing cooperative. The assumptions set forth on the production technology in (2) preclude *NARP* from ever becoming perfectly inelastic. Thus, the *OM* cooperative always responds to $dR > 0$ and the subsequent shift inward in its raw product supply curve by decreasing R^c so that its price response, dw^c, is less than $d\bar{w}$, the Cournot rival's response. This result, in turn, elicits more competitive behavior and a lower price spread than from the equivalent Cournot rival. Q.E.D.

The results in proposition 1 are consequences of the behavioral differences between the for-profit and co-op entities. For example, when *NARP* is increasing, the cooperative rationally reduces its price offer as market area and volume decrease in response to $dR > 0$. Thus, not only does the co-op fail to match a for-profit rival's price change, the co-op's price movement is opposite its rival's when *NARP* is increasing. The *H-S* conjecture posits no change in competitors' pricing while *C-N* and *LO* behavior, respectively, involve partial and full price matching. Recall that the greater the extent to which a raw product price increase is expected to be matched, the less profitable such competitive activity becomes, leading to high margins.

Part (*c*) of the proposition is especially important because the Cournot conjecture generates the Nash equilibrium in the quantity-setting game. We are thus assured that the *OM* co-op generates a lower price spread than would be obtained in equilibrium under competition among only Cournot rivals.

Worth noting also is that if $t \rightarrow 0$, i.e., spatial considerations are unimportant, $\gamma \rightarrow 1$ (from L'Hopital's rule) and from

$$\left(\frac{P-w)}{w}\right)^{OM} = \left(\frac{P-w)}{w}\right)^{H\text{-}S} = 0.$$

That is, in the nonspatial world, the open membership cooperative drives its rivals to the competitive solution.

Results for an open membership cooperative that sets (w^c, R^c) at the intersection of member supply and *NMRP* are similar to those for the *NARP*-pricing cooperative, but there are some differences. *NMRP* now plays the role of raw product demand for the cooperative, so except when *NMRP* = *NARP* at $R^c = R^*$, the two pricing schemes generate different (w^c, R^c) equilibria. As indicated previously (footnote 9), *NMRP* pricing must be complemented by a set of allocations to handle the break-even constraint which is satisfied automatically by *NARP* pricing. This fact complicates derivation of the rational conjecture for a processor competing with

an *NMRP*-pricing co-op. Derivation of the conjecture is contained in the appendix. The key result, though, is a logical consequence of optimal, *NMRP*-pricing versus second-best, *NARP*-pricing.

PROPOSITION 2. *A cooperative that attains the NMRP-pricing equilibrium generates less competitive behavior from its for-profit rivals than an equivalent cooperative that attains the NARP-pricing equilibrium.*

Proof. The *NMRP*-pricing cooperative responds optimally to any change in its raw product supply caused by a rival's behavior. The *NARP*-pricing cooperative responds in a second-best fashion. Because the *NMRP*-pricing cooperative responds optimally to any $dR > 0$ its market area will shrink less rapidly than for an otherwise identical *NARP*-pricing counterpart. That is, except at $R^c = R^*$, dL/dR is less when the for-profit processor faces an *NMRP* rather than an *NARP*-pricing co-op. Q.E.D.

The Restricted-Membership Cooperative

This section examines the competitive effect of the cooperative that restricts purchases to R^* and sets $w^c = w^* = NARP(R^*) = NMRP(R^*)$. The immediate consequence of this behavior is that the equilibrium condition of net price (10′) or net welfare (appendix equation A1) equality at the market boundary need not hold. Instead the condition at the market boundary, L, is

$$(24)\qquad w^c - t(u - L) \geq w - tL,$$

with strict inequality holding for (24) if the co-op faces excess supply at R^*.

The restricted-membership cooperative's behavior introduces a kink in the supply facing its noncooperative neighbor(s). Specifically, for

$$w \leq w^c + t(2L - u),$$

the noncooperative's market boundary is fixed in the direction of its restricted membership cooperative neighbor. That is, $dL/dR = 0$, the Loschian conjecture, in which case the for-profit processor acts as a monopsonist within its boundary.[11] Only for $w > w^c + t(2L - u)$ can the noncooperative attract supply from the cooperative members, in which case the cooperative would react, as described in the previous subsection or the appendix, by reducing purchases along either its *NMRP* or *NARP* function. The following proposition, thus, applies for the restricted membership cooperative:

PROPOSITION 3. *The rational conjecture for the for-profit processor facing a restricted membership cooperative (RC) setting price according to NARP is*

$$(25)\qquad (dL/dR)^{RC} = \begin{Bmatrix} 0 & \text{if } w \leq w^c + t(2L - u) \\ (\gamma/2t)(dw/dR) & \text{otherwise} \end{Bmatrix}.$$

Equation (A6) is substituted for $(\gamma/2t)(dw/dR)$ in (25) if the cooperative sets price according to NMRP.

As previous results have demonstrated, the greater is the dL/dR conjecture, the greater is the perceived total elasticity of grower supply response facing the processor. Competitive behavior is more desirable when the processor believes (rationally) that he can encroach upon the cooperative's market area. That is, he need raise w by a lesser amount to obtain a given increase in R if raising w raises L as well as increasing quantity supplied among the processors in L. This fact causes a kink at the price $w = w^c + t(2L - u)$ in the for-profit firm's perceived raw product supply function. This kink causes the firm's perceived marginal cost curve for the raw product to be discontinuous, introducing the possibility of multiple equilibria for the firm, depending upon where its net price, $P - m'$ intersects its perceived marginal costs of procuring raw product.

Competition with Both Cooperatives and For-Profit Rivals

Cooperatives and for-profit firms operate together in the typical agricultural market. Given different behavior between cooperative and for-profit processors, market areas need not be symmetric in the n directions of competition. Denote a representative for-profit processor's market area by the vector $L = \{L_1, \ldots, L_n\}$. Equation (6) can be rewritten to reflect heterogenous competitors as follows:

$$(6')\qquad \frac{dw}{dR} = \frac{\partial w}{\partial R} - \frac{1}{n}\sum_{j=1}^{n}\left[\frac{\partial R/\partial L_j}{\partial R/\partial w}\right]\frac{dL_j}{dR},$$

where (7) is used to substitute for $\partial w/\partial L$ in (6).

[11] The possibility that farmers excluded from the closed membership cooperative may form their own cooperative is explored in Sexton and Sexton.

Let n_1 of the rival processors be identical cooperatives and $n_2 = n - n_1$ be identical for-profit processors. Again denoting conjectures with θ, let $dL_k/dR = \theta^C(dw/dR)$, $k = 1, \ldots, n_1$ denote the rational conjecture for a firm faced with a cooperative competitor, where θ^C is defined in (20′), (25), or (A6) depending on the cooperative's behavior.

Let $dL_s/dR = \theta^{FP}dw/dR$, $s = n_1 + 1, \ldots, n$, denote the conjecture for a for-profit (*FP*) competitor's behavior, the magnitude of which depends on the perceived competitiveness in the market. Then substituting for dL_j/dR in (6′) and converting to the price spread obtains

$$(26)\quad \frac{p-w}{w} = \epsilon_{w,R}\left[\frac{1}{1 + (n_1/n)[(\partial R/\partial L_k)/(\partial R/\partial w)]\theta^C + (n_2/n)[(\partial R/\partial Ls)/(\partial R/\partial w)]\theta^{FP}}\right].$$

Clearly, if $\theta^C > \theta^{FP}$, competing with some cooperatives rather than all for-profit firms reduces a noncooperative's price spread. The likelihood of observing $\theta^C > \theta^{FP}$ has been shown here to depend critically on the structure of the market as manifest in the behavior of the cooperative's *NARP* and *NMRP* functions and on the membership policy of the cooperative.

To summarize, when *NARP* is increasing over the range of grower supply, open membership is the optimal policy, and proposition 1 indicates that a cooperative elicits more competitive behavior (a lower price spread) from its rivals than would a comparable for-profit processor conjectured to behave in a Loschian, Cournot-Nash, or Hotelling-Smithies fashion.

Conversely, a cooperative that fixes membership to maximize *NARP* provides a range of prices indicated by proposition 3 whereby a rival for-profit processor can rationally entertain Loschian conjectures and act like a monopsonist within its market area. A cooperative that maintains an open membership policy in spite of a diminishing *NARP* is predicted to have a more salutary effect on spatial competition than its closed-membership counterpart. From proposition 1, the *NARP*-pricing cooperative elicits a lower price spread from rivals than a comparable for-profit processor conjectured to pursue Cournot-Nash behavior.

Conclusions

Although the possible existence of a competitive yardstick effect for cooperatives has long been considered (e.g., see Cotterill), this paper is the first to document in a rigorous oligopsony model the membership, market structure, and technological conditions that determine the existence and magnitude of such an effect. The work offers a number of implications for public policy wherein agricultural cooperatives have traditionally held a favored position. Beneficial tax treatment, limited exemption from antitrust statutes under the Capper-Volstead Act, below-market interest rates, and free technical assistance through the USDA and extension services are among the most-cited examples of policy favorable to cooperatives.

Underpinning these policies is the presumption that cooperatives have an overall favorable impact on the economy. This belief is often challenged. For example, cooperatives have been criticized in respect to their use of marketing orders (Ippolito and Masson). And recently, Daniel Oliver, the chairman of the Federal Trade Commission (FTC), has called for elimination of cooperatives' antitrust exemption (American Institute of Food Distribution). Also important is recent criticism based on the results of econometric research that suggests cooperatives may be less efficient than other organization forms. Porter and Scully (pp. 511–12) conclude, for example, that "tax breaks, interest subsidies and the gratis services of The Department of Agriculture presumably compensate cooperatives for higher per-unit costs. These public resources provided to cooperatives foster and promote an inefficient form of organizing production. . . . To the extent that government policy promotes the emergence of and subsidizes the survival of, the inefficient cooperatives . . . more technically efficient for-profit proprietary firms may be prevented from emerging and developing."

The results described in this paper help justify favorable policies toward open membership cooperatives as procompetitive forces whose presence mitigates for-profit firms' opportunities to exercise monopoly or monopsony power. Any reexamination of policy should be limited to the minority of cooperatives that restrict membership and for which similar procompetitive effects cannot be claimed. Moreover, performance evaluations of cooperatives must be made carefully, recognizing that direct comparisons to rival for-profit enterprises may be misleading because the market presence of a cooperative likely causes its for-profit rivals to perform better than they otherwise would.

Further policy implications are in the area of antitrust, where the U.S. Justice Department merger guidelines explicitly recognize the importance of spatial factors in fomenting market power. This work indicates that opportunities to exercise spatial market power are diminished where one or more of the spatial competitors is an open membership cooperative, and, thus, it is less likely that horizontal mergers in these markets would have a significant anticompetitive effect. These procompetitive effects of cooperatives need to be considered when contemplating FTC Chairman Oliver's suggestion to dismantle the Capper-Volstead Act.

Profitable avenues for future research will be to develop and implement empirical models to test for the exercise of oligopsony power and the existence and magnitude of cooperatives' yardstick effect in specific markets. Methodologies to conduct parametric tests of market power have been developed in recent years (e.g., Appelbaum, and Karp and Perloff). These methodologies typically estimate the magnitude of a conjectural variation as part of a time-series econometric model of the industry under study. These models may be extended to also conduct tests of the procompetitive effect of cooperatives. For example, conjectural variations may be expressed as functions of the extent and magnitude of co-op competition as suggested by (26). The incremental data required to implement this generalized model are one or more variables, such as co-op market share, to measure the extent of co-op competition over time in the market.

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Appendix

The NMRP-Pricing Cooperative

Members of an *NMRP*-pricing co-op necessarily face a two-part pricing schedule, and the market boundary condition can no longer be stated as equality of net prices as in (10′). Rather, denoting as $\pi(W)$ a representative grower's well-behaved profit function, we have the boundary condition:

$$\text{(A1)} \qquad \pi(W^c) - \pi(W^n) = k$$

where W^c and W^n are, respectively, the grower's net price from the cooperative and noncooperative, and $k = k(R^c, L)$ is the fixed charge to the grower located on the market boundary L. If $m' > AC$, $k < 0$ is a rebate, and $W^c < W^n$ at the boundary.

The total deficit or surplus to the cooperative is $K = (AC - m')R^c$. It is assumed that K is allocated among members in proportion to their patronage. That is, for the boundary farm

(A2) $$k = (r^c/R^c)K,$$

where r^c denotes the quantity supplied by the boundary farm if it patronizes the cooperative. Consistent with the discussion in footnote 9, it is further assumed that the allocation is based on a fixed proxy for patronage so that members cannot influence the level of k by altering their volume of patronage.

Equation (A1) is an equilibrium identity that can be totally differentiated to obtain

(A3) $$\pi'(W^c)dW^c - \pi'(W^n)dW^n = dk.$$

This equation can be rewritten by using (A2) to express the differential dk as

$$dk = (r^c/R^c)dK + (K/R^c)dr^c - (r^cK/R^{c2})dR^c,$$

and by noting also the following:

$$dW^c = dw^c + tdL,$$

$$dW^n = dw - tdL,$$

$$\pi'(W^c) = r^c,$$

$$\pi'(W^n) = r^n,$$

where r^n denotes the quantity supplied by the boundary firm if it patronizes the for-profit processor. The latter two equalities are consequences of the envelope theorem. Substituting these expressions into (A3) and dividing by dR obtains

(A3′) $$r^c(dw^c/dR + tdL/dR) - r^n(dw/dR - tdL/dR) = (r^c/R^c)(dK/dR) + (K/R^c)(dr^c/dR) - (r^cK/R^{c2})dR^c/dR).$$

Equation (A3′) can be solved for the rational conjecture dL/dR for a firm competing with an *NMRP*-pricing open-membership cooperative. This is accomplished by first noting that K is just the inverse of the cooperative's "profit." Thus, it follows from the envelope theorem that

(A4) $$\frac{dK}{dR} = \frac{\partial K}{\partial w^c}\frac{dw^c}{dR} = R^c dw^c/dR.$$

Considering jointly the terms involving dr^c/dR and dR^c/dR on the right-hand side of (A3′), we obtain after expanding these derivatives:

(A5) $$\frac{K}{R^c}\frac{dr^c}{dR} - \frac{r^cK}{R^{c2}}\frac{dR^c}{dR} = \frac{K}{R^c}\left\{\frac{dw^c}{dR}\left[\frac{\partial r^c}{\partial w^c} - \frac{r^c}{R^c}\frac{\partial R^c}{\partial w^c}\right] + \frac{dL}{dR}\left[\frac{\partial r^c}{\partial L} - \frac{\partial R^c}{\partial L}\frac{r^c}{R^c}\right]\right\}.$$

The first bracketed term in (A5) vanishes due to homogeneity among farmers. Substituting (A4) and (A5) into (A3′) obtains the rational conjecture:

(A6) $$\frac{dL}{dR} = \frac{dw}{dR} \cdot \left\{\frac{r^n}{t(r^c + r^n) - (AC - m')[\partial r^c/\partial L - (r^c/R^c)\partial R^c/\partial L]}\right\}.$$

The expression $[\partial r^c/\partial L - (r^c/R^c)\partial R^c/\partial L]$ in the denominator of (A6) measures how the boundary farm's share of any co-op deficit or surplus changes in response to dR. The expression is always positive because raising L reduces $u - L$, the cooperative's market area, in turn causing $\partial R^c/\partial L < 0$. However, lower $u - L$ reduces transportation costs and raises supply for the border farm so that $\partial r^c/\partial L > 0$.

To evaluate behavior for the *NMRP*-pricing cooperative, consider the case where $R^c = R^*$ and $NMRP = NARP$. The two pricing schemes generate identical behavior and the identical, Hotelling-Smithies conjecture for a rational for-profit rival: $dL/dR = (1/2t)(dw/dR)$. (This result is verified from (A6) by noting that at R^*, $r^c = r^n$ and $AC - m' = 0$.)

When $R^c > R^*$, the *NMRP*-pricing cooperative generates a surplus and $r^c < r^n$. As R and w rise causing R^c to fall, the cooperative increases its total payout to members which is always monotonically increasing in *NARP*. This fact, as in the *NARP*-pricing case, makes $(dL/dR)^{OM} < (dL/dR)^{H\text{-}S}$ and, hence, discourages procompetitive behavior by the for-profit rival relative to the Hotelling-Smithies conjecture.

The opposite is true when $R^c < R^*$. Here the co-op incurs a deficit and $r^c > r^n$ for the border firm. Increases in w and R force the cooperative to diminish its total payout to members under *NMRP* pricing. Once again this fact makes $(dL/dR)^{OM} > (dL/dR)^{H\text{-}S}$, which induces more procompetitive behavior by the rational for-profit rival and a lower farm–processor price spread relative to the Hotelling-Smithies benchmark.

Investment Potential of Agricultural Futures Contracts

T. Randall Fortenbery and Robert J. Hauser

Investment benefits from trading live cattle, hog, corn, and soybean futures contracts are considered under the assumption that the investor's risk/return evaluation is relative to a highly diversified stock portfolio. A mean-variance approach is used to find the "optimal" mix of investments for the initial stock portfolio and for portfolios which may include both stocks and futures. The addition of futures contracts to the portfolio rarely increases the portfolio return. This finding is consistent with risk-premium results of previous studies. However, investment benefits from agricultural futures are found in the form of a reduction in the portfolio's nonsystematic risk.

Key words: futures contracts, investment, mean-variance analysis, risk premium.

What determines benefits from a position in the futures market? Keynes argued that a systematic risk premium is gained by speculators for offsetting hedgers' positions. A different but commonly used concept of "risk premium" involves the degree to which the variability of the returns to an instrument or activity cannot be diversified away. This perspective on risk is the foundation of the standard capital asset pricing model (CAPM) developed by Sharpe and by Lintner. As the level of systematic risk of an activity increases, the risk premium increases. That is, the market will compensate an investor for risk that can not be eliminated.

Keynes' notion of risk and its premium is only a function of the price return for an individual futures contract. The Sharpe/Lintner definition of risk and its premium relies on the return behavior of the completely diversified portfolio. The objective of our study is to identify and measure the investment benefits of agricultural futures contracts to investors or speculators whose concept of risk/return may fall between these extremes.[1]

The speculator's evaluation of risk/return is relative to his current portfolio. In contrast, the CAPM approach considers the perfectly diversified portfolio. However, the CAPM concept has at least two practical problems. First, an individual may make the evaluation relative to his own portfolio, regardless of whether the market is determining risk premiums based on the market portfolio. Our approach, through mean-variance (EV) analysis, recognizes that speculative rewards are a function of the specific investor and investment set considered, emphasizing that investors may hold portfolios which contain nonsystematic risk. The second problem with the CAPM approach involves the definition and measurement of the market portfolio. Dusak, for example, was criticized for her market-portfolio proxy by Carter, Rausser, and Schmitz, who in turn were criticized for their choice by Marcus and by Baxter, Conine, and Tamarkin. These and other debates reflect the fact that the CAPM approach requires an a priori assumption about the optimal portfolio mix. The present analysis determines the "optimal" mix of investments in the initial portfolio given a set of investments from which to choose.

Methodology

To measure the investment potential of futures contracts, efficient EV frontiers are estimated for portfolios with and without futures contracts as an investment option. If investment benefits from futures contracts exist, then the frontier that includes the futures contracts will attain a higher level of risk-efficiency, as illustrated in figure 1. The increase in risk efficiency is measured

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[1] The terms speculator and investor are used interchangeably here because the analysis considers the portfolio effects of a stock investor who expands his investment set to include futures speculation.

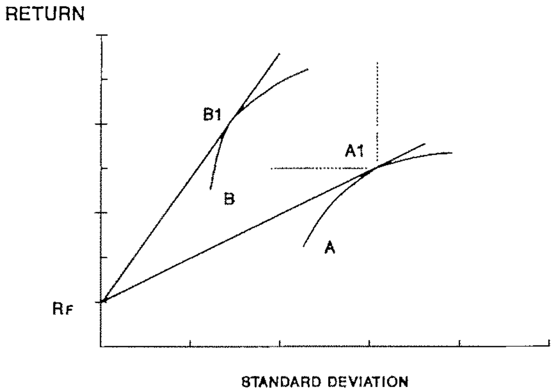

Figure 1. Illustration of return and risk management benefits

by defining optimal risky portfolios in each EV frontier. Following Elton and Gruber, these portfolios are found at the tangency between the EV frontier and the capital market line, represented by points $A1$ and $B1$.

Two types of benefits are created by an upward shift in the EV frontier. The first type is represented by the difference between expected returns, while the second is reflected by the difference in the standard deviations of returns. An increase in expected return is a "return benefit;" a decrease in standard deviation is a "risk management benefit." Both types of benefit are represented in figure 1 because the optimal portfolio of frontier B lies inside the quadrant defined by the dashed lines.

EV analysis allows empirical measurement of benefits which are unique to the investor, depending on the initial portfolio mix. The approach used here is similar to that used by Howard and D'Antonio, except that the focus is on speculators rather than on hedgers, and the value of the futures contract is measured differently.

The initial investment set is assumed to consist solely of stocks traded at the New York Stock Exchange. The stock frontier is found with the following quadratic programming (QP) specification:

$$\text{(1)}\quad \text{Minimize } V(Z)^{1/2} = \left[\sum_{i=1}^{n}\sum_{j=1}^{n} q_i \sigma_{ij} q_j\right]^{1/2},$$

subject to

$$\sum_{i=1}^{n} q_i U_i \geq M,$$

$$\sum_{i=1}^{n} q_i = 1,$$

$$q_i \geq 0 \text{ for } i = 1,2,\ldots,n,$$

where $V(Z)$ is the variance of the portfolio return, q_i is the proportion of each risky investment i in the portfolio, σ_{ij} is the variance-covariance matrix of expected rates of return, U_i is the expected rate of return for investment i, and M is the minimum acceptable rate of portfolio return. The model is solved iteratively with parametric variations in M of 0.01% per month.

A highly diversified stock portfolio is found by using the four individual indices of the Standard and Poor's 500 Stock index. The indices represent utility, industrial, financial, and transportation stocks.[2] While the EV approach does not require a well-diversifed portfolio, a diversified portfolio is used here so that the results are comparable to those found by Bodie and Rosansky, Dusak, and Lee and Leuthold. These studies measure risks and benefits of futures under the assumption that the Standard and Poor's 500 index represents a completely diversified portfolio.

Using data from July 1976 to December 1985, monthly returns to stock portfolios are computed as the percentage change in average monthly index values plus the average monthly rate of dividend returns to each index. An EV frontier is then estimated using the four stock indices as the investment set. The resulting capital market line is defined by the highest linear function between the risk-free rate of return (represented by the 90-day treasury bill rate) on the vertical axis and the tangency on the EV frontier. The tangency point between the capital market line and the EV frontier represents the optimal risky portfolio.

Individual futures contracts are then added to the investment set and the EV frontier is reestimated. The optimal portfolio for the new EV frontier is identified, allowing measurement of the return and risk management benefits.[3] Following Bodie and Rosansky, the return to the futures positions is calculated as the monthly percentage changes in the futures prices plus the risk-free rate of return. They argue that returns to futures contracts can be measured and compared to returns to stocks in two ways. The first is to calculate returns to futures as the proportional change in futures price:

$$R_{1t} = (P_{t+1} - P_t)/P_t,$$

[2] Each stock of the Standard and Poor's 500 is weighted such that changes in its price influence the index in proportion to the stock's relative market value. The individual indices of the Standard and Poor's 500 are comprised of the 500 stocks categorized by industry.

[3] An equilibrium framework is not employed, and thus portfolio adjustments are not evaluated on the basis of risk attitude, wealth, and/or new investment opportunities.

where R_{1t} is the futures return, P_{t+1} is the futures price in period $t + 1$, and P_t is the futures price in period t. Bodie and Rosansky use this measure for comparison against the net return of stocks. The stocks' net return is the return to a stock position in excess of the 90-day treasury bill rate (i.e., in excess of the risk-free rate of return).

The second method for computing returns to futures accounts for the ability of speculators to post treasury bills as margin. To avoid problems associated with marking futures positions to market daily (i.e., settling all futures gains and losses at the end of each business day), Bodie and Rosansky consider the treasury bill interest earned on average equity in futures over the investment period. This led to the following measure of futures return:

$$R_{2t} = ((P_{t+1} - P_t) + R_{ft}(P_t + P_{t+1})/2)/P_t,$$

where R_t and P_t are as before, and R_{ft} is the 90-day treasury bill rate in period t. This return was then compared to the gross stocks' return. Note that when P_{t+1} and P_t are close in value, R_{2t} will be approximately equal to the proportional change in futures price plus the 90-day treasury bill rate:

$$R_{2t} \approx R_{1t} + R_{ft}.$$

We use this approximation of R_{2t} by defining R_{ft} as the average 90-day treasury bill rate for period t.

The investment benefits of four agricultural futures contracts are examined: live cattle, hogs, corn, and soybeans. Combinations of the contracts also are considered. Finally, positions in the Commodity Research Board's Commodity Futures Index (CFI) are examined to reflect a diversified holding of futures positions.[4] The mean return and standard deviation of a long position is reported by futures contract in table 1. Correlations between the futures and index returns are also presented. The return levels relative to their standard deviations suggest that Keyensian risk premiums are not present. However, the small correlation coefficients indicate that agricultural futures may provide diversification benefits.

Several trading scenarios are modeled for each contract. The first is a routine buying strategy where the investor trades long in the nearby contract. Because futures contracts do not expire every month, positions are opened and closed only in those months preceding contract expiration. Monthly observations are calculated by dividing the gross return of a futures trading strategy by the number of months the position is held. For example, gross returns for live cattle contracts are divided by two because these contracts expire every other month; thus, a position is opened and closed every two months.[5]

The second trading scenario is the same as the first, except the investor takes a short position in the nearby contract. The third and fourth strategies are the same as the first and second, respectively, except that a position is taken in a contract that is approximately six months from maturity. This position is offset and a position is taken in the next distant contract when that contract is six months from maturity. These last two strategies are employed to evaluate potential differences in the risk or return characteristics that are attributable to contracts of different maturities.

[4] Similar in construction to a stock index, the CFI is based on 27 commodities which include both agricultural and nonagricultural futures contracts.

[5] The assumption that the return to a position held for two months can be equally divided between the two months ignores compounding. This is not considered critical, however, because an average is never computed for more than a two-month investment period.

Table 1. Relationships between Futures and Stock Returns

			Correlation Coefficients			
Futures[a]	Mean	Standard Deviation	Financial	Transportation	Utility	Industrial
N. Cattle	0.39	3.84	.018	−.066	−.148	.021
N. Hogs	0.53	5.19	−.056	.091	.016	.116
N. Corn	−0.36	4.06	.001	.150	−.029	.200
N. Soybeans	−0.73	5.77	.067	.226	.019	.199
D. Cattle	0.03	2.78	−.046	−.005	−.179	.053
D. Hogs	0.38	4.88	−.142	−.017	−.143	−.003
D. Corn	−0.50	3.57	.019	.160	.011	.186
D. Soybeans	0.22	5.14	.057	.228	.062	.231
CFI	−0.09	2.85	−.023	.227	−.032	.254

[a] "N." signifies nearby contract; "D." is distant contract.

Results

EV frontier *A* in figure 2 represents the estimated set of risk-efficient portfolios attainable by an investor who views his investment alternatives to consist solely of the four stock indices. Given a risk-free rate of return equal to the 90-day T-bill rate, the optimal risky portfolio has an expected monthly rate of return of 1.29% and a standard deviation of 2.47% per month.[6]

The effects of adding long nearby live cattle contracts to the stock investment set are also shown in figure 2. The addition of the cattle contract causes the EV frontier to move to the left, indicating that trading benefits are available for the nearby live cattle contract traded long. These benefits as well as those for other contracts are quantified in table 2.

When measured at the points of the optimal risky portfolio, the live cattle futures contract does not provide return benefits for any of the trading strategies. However, risk management benefits are indicated. The greatest risk management benefit is derived from trading the live cattle contract long. Trading the nearby contract long reduces risk by 0.28% per month with no change in the expected rate of return, while trading the distant contract long results in a risk reduction of about 0.52% per month and a reduction in the expected rate of return of about 0.12% per month.

The risk efficiency results for hog futures are similar to those for live cattle (table 2). For nearby live cattle traded long, the futures contract represents 26.19% of the portfolio; for hogs, it is 17.92%. In the CAPM framework, Bodie and Rosansky argue that agricultural futures should comprise 40% of the optimal market portfolio, whereas Marcus contends that 10% is more appropriate. For the investor considered here the optimal percentage of individual livestock futures in the portfolio falls between these two estimates.

The results from including corn contracts in the feasible investment set are similar to those for livestock except that the largest risk management benefit is derived from trading corn short rather than long. When corn is traded short on the nearby contract, frontiers similar to those for nearby live cattle traded long are generated. As shown in table 2, trading the nearby corn contract short yields no return benefit, but a measurable risk management benefit exists. This same result is generated when the distant corn contract is traded short. When either corn contract is traded long, trading rewards are negligible.

For soybean futures, long positions in either the nearby or distant contracts yield no return benefits, although some risk management benefit occurs if the distant soybean contract is traded long. The nearby contract traded long is not even on the efficient frontier.

[6] The standard deviation of expected returns is used here as a proxy for risk. A risk level, for example, of 3% per month is equivalent to a standard deviation of expected monthly returns of 3%.

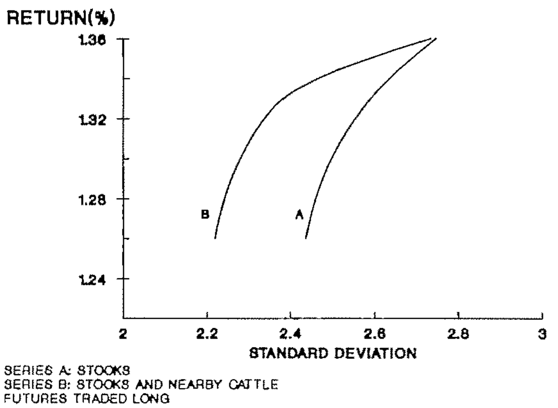

Figure 2. Effect of trading nearby live cattle futures long

Table 2. Optimal Portfolio Characteristics When Individual Futures Contracts Are Included in the Investment Set

Investment	Return[a]	Risk[a]	Percentage of Optimal Portfolio
All stocks	1.29	2.4727	100
Cattle contracts			
Nearby long	1.29	2.1893	26.190
Nearby short	1.23	2.1893	7.446
Distant long	1.17	1.9570	26.677
Distant short	1.15	1.9525	26.111
Hog contracts			
Near long	1.29	2.2378	17.923
Near short	1.29	2.4717	0.5316
Distant long	1.27	2.1843	19.092
Distant short	1.25	2.3603	5.5026
Corn contracts			
Near long	1.29	2.4680	1.4404
Near short	1.26	2.1675	22.694
Distant long	1.28	2.4503	1.4384
Distant short	1.28	2.0827	30.758
Soybean contracts			
Near long	1.29	2.4727	0.0000
Near short	1.33	2.3355	16.735
Distant long	1.27	2.2211	3.4799
Distant short	1.27	2.2211	3.4799

[a] Measured as percent per month.

Figure 3 shows the frontier derived by including the nearby soybean futures contract traded short in the investment set compared to the original all-stock frontier. At the maximum rate of return, 1.36% per month, the frontier that includes soybeans lies to the left of the all-stock frontier. In all other cases this rate of return was a point of convergence between the frontiers including and excluding futures contracts. Moreover, only when trading the nearby soybean futures contract short does the expected rate of return to the optimal portfolio increase when an individual futures contract is included in the investment set. However, the increase in return is only 0.04% per month, and the risk management benefit in this case is small relative to the risk management benefit identified for other strategies.

Table 3 presents the results of including combinations of futures contracts in the portfolio. Increased speculative benefits are associated with diversifying in either the livestock or grain futures markets. When both grains are held short, a return benefit is realized. The portfolio return is 1.35% per month with a risk level of 1.84%.

Results are also generated under the assumption that the investor holds either a long or short position in the CFI to proxy the effects of being totally diversified in the futures market. A nearby strategy is considered. As table 3 indicates, little difference occurs between trading the CFI index short or long. Some portfolio risk reduction is available from either strategy but at a substantial reduction in expected portfolio return. Thus, several strategies for both individual and combined contracts represent superior investments to the CFI index.

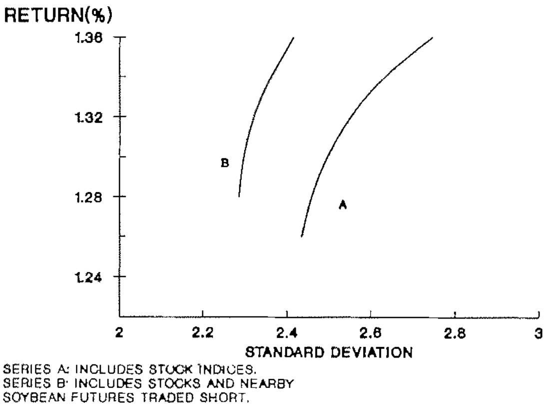

Figure 3. Effect of trading nearby soybean futures short

Table 3. Optimal Portfolio Characteristics When Trading More Than One Futures Contract

Investment	Return (%/Mo.)	Risk (%/Mo.)	Percentage of Optimal Portfolio
All stocks	1.29	2.4727	100
Livestock contracts			
Nearby long	1.27	2.0209	
Cattle			21.736
Hogs			9.7252
Nearby short	1.23	2.3119	
Cattle			7.4362
Hogs			0.0900
Distant long	1.18	1.8905	
Cattle			19.593
Hogs			12.248
Distant short	1.15	1.9526	
Cattle			26.107
Hogs			0.0000
Grain contracts			
Nearby long	1.29	2.4680	
Corn			1.4404
Soybeans			0.0000
Nearby short	1.35	1.8376	
Corn			9.1230
Soybeans			39.075
Distant long	1.27	2.2216	
Corn			0.0000
Soybeans			3.4799
Distant short	1.23	2.0243	
Corn			28.947
Soybeans			4.2255
Futures index			
Long	1.19	2.0428	25.6666
Short	1.18	2.1191	19.2660

Concluding Comments

The EV model used in this study is useful for identifying investment potential or speculative rewards of futures contracts. The methodological approach differs from previous work in two fundamental ways. First, it allows measurement of both the "return benefit" and "risk management benefit" of future market investments. Previous analyses focus primarily on return benefits in the form of risk premiums. However, the absence of futures market "risk premiums" does not imply an absence of speculative rewards. To conclude that no speculative rewards exist for a given speculator, one must also show that portfolio risk is not reduced by the addition of a future position. The second difference is that the EV model allows return and risk management benefits to vary across investors and across commodities. Rewards to futures speculation may be a unique function of a specific

portfolio's risk and return characteristics. Previous studies have often assumed that the existence and magnitude of risk premiums are market phenomena. Thus, all speculators were expected to receive identical rewards from similar futures market positions.

Return benefits are generally not found for the investor characteristics and strategies considered here. This finding is consistent with the risk premium results of Dusak, Lee and Leuthold, and others. However, our study suggests that trading benefits associated with including some futures contracts in the investment set occur as reductions in portfolio risk. This finding supports previously untested hypotheses that futures contracts can diversify the nonsystematic risk components of stock portfolios (Dusak, Lee and Leuthold, Bodie and Rosansky).

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The RLS Positive-Part Stein Estimator

Lee C. Adkins and R. Carter Hill

The RLS Stein-rule estimator of the classical normal linear regression model is formed by taking a linear combination of the least squares and restricted least squares estimators. Using a simple analytical device, we prove that the convex combination known as the RLS positive-part Stein estimator dominates the conventional version under weighted quadratic loss. Possible uses for the positive-part estimator in economic and agricultural economic research are discussed.

Key words: biased estimation, restricted least squares estimator, Stein-rule estimator.

Although it is well known that positive-part Stein rules dominate ordinary versions in many general settings, such a result has not been obtained for an important family of Stein estimators. We respond to the conjectures of Hill, Ziemer, and White; and Mittelhammer and Young, who claim that the Stein rule, which is formed by taking a linear combination of OLS and RLS estimators, is dominated by the convex combination called the positive-part Stein rule. By using a simple analytical device, we prove that the positive-part rule dominates the conventional version under weighted quadratic loss.

In the next section the classical normal linear regression model and its estimators are presented. Then the canonical form for the Stein-rule estimator is derived and the desired result is deduced using the canonical form and results given in Judge and Bock. Finally, the properties and potential uses of the positive-part Stein rule are discussed.

The Model and Its Estimators

The classical normal linear regression model (CNLRM) is represented by

(1) $$y = X\beta + e \quad e \sim N(0, \sigma^2 I_T),$$

where y is a $T \times 1$ vector of observable random variables, X is a nonstochastic $T \times K$ matrix of rank K, β is a $K \times 1$ vector of unknown parameters, and e is a $T \times 1$ vector of unobservable normally and independently distributed random variables having zero mean and finite variance σ^2. The ordinary least squares (OLS) and maximum likelihood estimator of β is $b = (X'X)^{-1}X'y \sim N(\beta, \sigma^2(X'X)^{-1})$, and the minimum variance unbiased estimator of σ^2 is $\hat{\sigma}^2 = (y - Xb)'(y - Xb)/(T - K)$, with $(T - K)\hat{\sigma}^2/\sigma^2 \sim \chi^2_{T-K}$ and independent of b.

Judge and Bock (pp. 240–42) proposed a family of Stein-rule estimators which dominates the MLE of β in the CNLRM under weighted quadratic loss with weight matrix W. Their estimator is a linear combination of the unrestricted and restricted MLEs and has the form

(2) $$\delta(b) = (1 - c/u)b + (c/u)b^*,$$

where $u = (Rb - r)'(RS^{-1}R')^{-1}(Rb - r)/J\hat{\sigma}^2 \sim F_{J,T-K,\lambda}$ is the conventional F-statistic used to test the hypothesis restrictions H_0: $R\beta = r$, $S = X'X$; R is a known $J \times K$ nonstochastic matrix of rank J; r is a $J \times 1$ vector of known constants; $b^* = b - S^{-1}R'(RS^{-1}R')^{-1}(Rb - r)$ is the restricted least squares estimator (RLS); $\lambda = (R\beta - r)'(RS^{-1}R')^{-1}(R\beta - r)/2\sigma^2$ is the noncentrality parameter; and $c = a(T - K)/J$. The estimator is minimax if the scalar a is chosen to lie within the interval $[0, a_{\max}]$, where

(3) $$a_{\max} = [2/(T - K + 2)] \cdot \{\lambda_L^{-1} \operatorname{tr}[(RS^{-1}R')^{-1}RS^{-1}WS^{-1}R'] - 2\},$$

and λ_L is the largest characteristic root of $[(RS^{-1}R')^{-1}RS^{-1}WS^{-1}R']$. The value of the constant a which minimizes quadratic risk is the interval's midpoint.

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In many circumstances, the usual Stein estimator is dominated by a simple modification called the positive-part rule. The positive-part rule associated with (2) is denoted

$$(4)\qquad \delta^+(b) = \begin{bmatrix} b^* & \text{if } c > u \\ \delta(b) & \text{if } c \le u. \end{bmatrix}$$

Both Hill, Ziemer, and White; and Mittelhammer and Young correctly claim that the usual Stein rule is dominated by its positive part. Below, we will prove that their conjecture is true by showing that (4) dominates (2) under arbitrary quadratic loss using a simple analytical device which can be easily applied in many similar circumstances.

The Canonical Form

To show dominance of (2) by (4), the model and the hypothesis restrictions are written in their canonical forms. Let

$$(5)\qquad y = X\beta + e = XPP^{-1}\beta = Z\theta + e,$$

where $Z = XP$, $\theta = P^{-1}\beta$, and P is such that $P'X'XP = I$. Under the same transformation the restrictions $R\beta = r$ become $RPP^{-1}\beta = H_1\theta = r$. The rank of H_1 is J; therefore, there exists a nonsingular matrix, C, such that $CH_1 = [I_J\ 0]$; hence the restrictions can be written $CH_1\theta = Cr = H\theta = h$, where $H = CH_1\theta$ and $h = Cr$. The model is now $y = Z\theta + e$ subject to the simple equality restrictions $H\theta = [I_J\ 0]\theta = \theta_J = h$. The least squares estimator, restricted least squares estimator, and test statistic are $\hat{\theta} = Z'y \sim N(\theta, \sigma^2 I_K)$, $\theta^{*\prime} = (h', \hat{\theta}'_{K-J})$, and $u = (\hat{\theta}_J - h)'(\hat{\theta}_J - h)/J\hat{\sigma}^2$, respectively, where $\hat{\theta}_{K-J} = [0\ I_{K-J}]\hat{\theta}$ and $\hat{\theta}_J = [I_J\ 0]\hat{\theta}$.

For the problem at hand, the analytical advantages of this canonical form are substantial. The regression model subject to linear constraints has been transformed into the problem of estimating the mean of a multivariate normal distribution subject to simple equality restrictions $\theta_J = h$. It is a simple matter to derive the desired result in this context.

Result

The goal is to prove that (2) is dominated by the positive-part Stein rule given in (4). To obtain this result, we use the transformation described in the previous section along with a known result from the literature on Stein estimation.

Judge and Bock (pp. 245–48) prove that b_g^+ dominates b_g under arbitrary quadratic loss functions where

$$(6)\qquad b_g = [1 - c/u]b + (c/u)b_0,$$

$$(7)\qquad b_g^+ = \begin{bmatrix} b_0 & \text{if } c > u \\ b_g & \text{if } c \le u, \end{bmatrix}$$

$J = K$, and b_0 is a $K \times 1$ vector of known constants.

The Stein estimator (2) defined in terms of the transformed parameter space is

$$(8)\qquad \delta(\hat{\theta}) = [1 - (c/u)]\hat{\theta} + (c/u)\theta^*, \text{ or}$$

(9)

$$\delta(\hat{\theta}) = \begin{bmatrix} [1 - (c/u)\hat{\theta}_J + (c/u)h \\ \hat{\theta}_{K-J} \end{bmatrix} = \begin{bmatrix} \delta(\hat{\theta}_J) \\ \hat{\theta}_{K-J} \end{bmatrix}.$$

Because $\hat{\theta}_J$ is statistically independent of $\hat{\theta}_{K-J}$ and $E[\hat{\theta}_{K-J}] = \theta_{K-J}$, the quadratic risk of using $\delta(\hat{\theta})$ to estimate θ is

$$(10)\qquad R(\delta, \theta) = R(\delta(\hat{\theta}_J), \theta_J) + R(\hat{\theta}_{K-J}, \theta_{K-J}).$$

The risk of using least squares, $\hat{\theta}$, to estimate θ is

$$R(\hat{\theta}, \theta) = R(\hat{\theta}_J, \theta_J) + R(\hat{\theta}_{K-J}, \theta_{K-J}).$$

Thus, $\delta(\hat{\theta})$ dominates $\hat{\theta}$ if

$$R(\delta(\hat{\theta}_J), \theta_J) \le R(\hat{\theta}_J, \theta_J).$$

Similarly, the positive-part rule, $\delta^+(\hat{\theta})$, which is equal to θ^* if $(c/u) > 1$ and $\delta(\hat{\theta})$ otherwise, will dominate $\delta(\hat{\theta})$ if

$$R(\delta^+(\hat{\theta}_J), \theta_J) \le R(\delta(\hat{\theta}_J), \theta_J).$$

As given, $\delta(\hat{\theta}_J)$ is equivalent to (6) with $K = J$, and the Judge and Bock result can be applied to this expression directly.

In the context of the transformed model the quadratic loss function associated with use of an arbitrary estimator of θ, call it $\tilde{\theta}$, is

$$\begin{aligned} L(\tilde{\theta}, \theta, W^*) &= (\tilde{\theta} - \theta)'W^*(\tilde{\theta} - \theta) \\ &= (\tilde{\beta} - \beta)'P^{-1\prime}W^*P^{-1}(\tilde{\beta} - \beta). \end{aligned}$$

Squared error loss in the θ-space is equivalent to mean square error of prediction loss in the original β parameter space, i.e., $L(\tilde{\theta}, \theta, I_J) = L(\tilde{\beta}, \beta, X'X)$. For squared error loss in the β-space, let $W^* = P'P$. The constant $a_{\max}$ in the transformed model is obtained by substituting $R = [I_J\ 0]$, $S = I$, and $W = W^*$ into (3) and the Stein-rule or positive-part Stein-rule estimator is minimax if the number of restrictions (J) is strictly greater than two.

The mean, covariance, and risk of the RLS Stein rule and its positive part may be obtained similarly using existing results for (6) and (7) in conjunction with the canonical form. The usefulness of these results is limited in practice because they depend on the unknown parameters, β and σ^2. Replacing the unknown parameters in the moment expressions with consistent estimators like the unrestricted MLEs or Stein rules yields statistics and interval estimators with unknown sampling distributions. Though biased, the Stein rule (2) has lower risk than the unrestricted MLE, and the positive-part rule (4) has lower risk than the usual Stein rule; these are sufficient reasons to use the positive-part rule for point estimation in applications. Work is under way on procedures to evaluate the small-sample precision of (2) and (4) and on interval estimation techniques based on the Stein rules. See, for example, Adkins; Adkins and Hill; and Ullah, Carter, and Srivastava.

Discussion

The positive-part rule takes a convex combination of the unrestricted and restricted MLEs; geometrically, this means that (4) lies between b and b^*. The positive-part rule is intuitively appealing because it draws, or "shrinks," the unrestricted estimates toward, but not past, the restricted estimates. The usual Stein estimator (2) is less attractive because it changes the sign of the unrestricted MLEs whenever the value of the test statistic, u, is smaller than the constant, c.

The positive-part Stein rule can be used whenever one has uncertain nonsample information involving three or more linear parameter restrictions. These situations are common in agricultural economics and a wide range of potential applications can be found. Consider the following. First, one may have panel data consisting of multiple observations on several cross-sectional units and suspect that the dependent variable responds similarly to changes in the exogenous variables, X, across units. The (uncertain) equality of coefficients across units can be represented by a set of linear parameter restrictions. Second, Almon polynomial distributed lag models require one to choose lag length and polynomial degree which impose linear restrictions on coefficients of the distributed lag. These exact restrictions on the parameters are only approximately true at best. Third, principal components regression is sometimes recommended for models estimated using poorly conditioned data (i.e., in the context of near multicollinearity). The deletion of principal components from the model imposes exact, sample specific, linear constraints on the model's parameters which are often difficult to interpret and evaluate. Once again, these restrictions are only approximately true and the positive-part RLS Stein rule can be used to obtain a risk improvement.

Additional examples can be found in production theory in which under certain circumstances production functions are homothetic in the inputs. Depending on the functional form used, homotheticity often implies restrictions of the form $R\beta = r$. Similarly, in demand equations Engle aggregation or homotheticity restrictions can often be expressed in the $R\beta = r$ form and used with the linearized equation.

Another possibility to consider when faced with uncertain linear parameter restrictions is to assume that the information they embody is correct and to impose the restrictions on the model's parameters using the RLS estimator. Unfortunately, the risk of the RLS estimator is unbounded and increases with the value of the noncentrality parameter, λ, which measures the specification error implicit in the restrictions. A common econometric practice is to treat the restrictions as a hypothesis and employ them if they cannot be rejected by conventional tests. The resulting pretest estimator, which selects either the MLE or RLS estimators based on the outcome of the hypothesis test of the restrictions $R\beta = r$, has greater risk than the MLE (or the Stein rules) over large regions of the parameter space. The positive-part Stein rule, which combines the MLE and RMLE, has uniformly lower risk than the MLE under arbitrary quadratic loss and may be used in any of these situations.

In the presence of uncertain nonsample information an appealing alternative to pretesting is to adopt a Bayesian procedure which uses a prior distribution on the parameters (or the sampling "equivalent," mixed estimation). The Stein rules have been shown to be empirical Bayes rules (Judge, Hill, and Bock); consequently, they are formal as well as intuitive alternatives to pretesting which have desirable statistical properties.

Concluding Comments

In general, most researchers should use positive-part Stein rules rather than the usual ones

because they are known to have smaller quadratic risk under general circumstances. In this article, we have shown that a general family of Stein rules mentioned in Judge and Bock, extended by Mittelhammer and Young, and generalized by Mittelhammer (1984, 1985) is in fact dominated by the positive-part rule which sets the Stein estimator equal to the RLS estimator whenever the shrinkage factor $(c/u) > 1$. In addition, some possible uses for the positive-part rule in economic and agricultural economic research have been discussed.

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Comments and Replies

The Effects of Food Stamps on Food Expenditures: Comment

Phillip S. Kott

In a recent issue of the *Journal*, Devaney and Fraker compared weighted and unweighted regression analyses performed on data from a complex sample the 1977–78 Nationwide Food Consumption Survey, (NFCS) low-income sample. The authors had some difficulty interpreting their findings. Perhaps this comment can be of some assistance.

Suppose an analyst wants to perform a regression with sample survey data. Suppose further that the sample has been drawn with unequal probabilities of selection reflecting a design variable which is not incorporated into the analyst's regression model.

Holt, Smith, and Winter have noted that probability weighting appears to control for the bias in ordinary least squares when both the dependent and independent variables of the regression are correlated with the design variable. This suggests that when weighted and unweighted regression yields meaningfully different values for a particular coefficient (in Devaney and Fraker's case, MFC_f), the model may be underspecified. That is to say, a more complete model would include some function (or functions) of the design variable.

Adding dummies for stratification variables in an unweighted analysis (the authors consider such dummies in a weighted context) may sometimes address the underspecification problem, but not always. One possibility in the authors' example is that a separate MPC_f for households in low-poverty areas is needed.

It should be noted that the rationale for weighting given above is much different from that in generalized least squares (GLS) theory. As a result, GLS-based estimated standard errors—like those derived using SAS and most conventional regression programs—are meaningless in this context.

There are regression packages designed specifically for use with data from complex samples. Two that I like are PC CARP (Fuller et al.) and SURREGR (Holt).

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The Effects of Food Stamps on Food Expenditures: Reply

Barbara Devaney and Thomas Fraker

In his comment on our recent article in *AJAE* (Devaney and Fraker), Kott notes that GLS-based standard errors are biased when generated by standard regression packages from complex sample survey data. While it is true that the standard errors of the estimates of the marginal propensity to consume food (MPC_f) out of food stamp benefits that are given in tables 2 and 3 of our article are incorrect, there remains statistically sound evidence in support of the central thesis of our article: the estimates of the MPC_f out of food stamps that are generated by conventionally specified models of food expenditures on the basis of data from the Nationwide Food Consumption Survey (NFCS) are highly sensitive to whether the sample weights are used in the estimation process.

Let us assume that Y is the dependent variable in a regression equation, X is a row vector of explanatory variables, W is a variable which holds the values of the sample weights associated the units of observation in the survey data file, and Z is a row vector of the sample-weighted explanatory variables ($Z = X'W$). DuMouchel and Duncan observe that the t-statistics associated with the coefficients on Z in an unweighted regression of Y on X and Z are good approximations to the t-statistics for the difference between corresponding coefficients in weighted and unweighted regressions of Y on X. We used that relationship to test whether there is a difference between the weighted and unweighted estimates of the MPC_f out of food stamps that are generated by our food expenditure model. Our results show that the weighted and unweighted estimates of this parameter are different at the 7% level of statistical significance. Furthermore, the difference between the two estimates is very large from the perspective of policy makers who, on the basis of such estimates, must draw conclusions regarding the efficiency of the food stamps in augmenting food expenditures.

We agree with Kott's observation that the large difference between the weighted and unweighted estimates of the MPC_f out of food stamps is symptomatic of an underspecified model; however, we wish to point out that our model is very similar to those used in previous studies of the effects of food stamps on food expenditures. Indeed, our discovery that the variation in the estimates of the MPC_f found in previous studies was due primarily to the use or nonuse of sample weights, rather than to more complex statistical issues, suggested model specification bias and prompted us to alert other researchers to this finding. As reported in our article, we attempted to improve the specification of the model by adding dummy variables for NFCS sample stratifiers. We used both weighted and unweighted data to estimate the expanded model; and, following Method A on page 539 of DuMouchel and Duncan, we conducted an F-test for equality between the two vectors of regression coefficients. On the basis of that test, we were unable to reject the null hypothesis of equality. Thus, the test indicates that the expanded model is not underspecified; nevertheless, the difference between the weighted and unweighted estimates of the MPC_f that are generated by that model is nearly as large as the difference obtained using the base model. The importance of this finding is that researchers cannot be complacent regarding the choice between weighted versus unweighted data simply because their models satisfy this test for misspecification.

Kott speculates that both the base model and the expanded model may be underspecified in that they do not allow for the possibility that the MPC_f out of food stamps may be different in low-poverty areas than in medium- or high-poverty areas. Support for his hypothesis is provided by our own preliminary analysis, which indicates that the MPC_f may in fact be much larger for food stamp recipients who reside in low-poverty areas than for other recipients. Additional research on this aspect of the model specification problem is needed.

In conclusion, we encourage all researchers to note carefully Kott's warning regarding the limitations of standard regression packages when applied to sample survey data. We also believe that his suggestion that the MPC_f out of food stamps may vary across poverty strata warrants further investigation. However, neither of these points detracts from the validity of the principal conclusions that can be drawn from our analysis: (*a*) estimates of the MPC_f out of food stamps that are generated by applying a conventionally specified model of household food expenditures to data from the NFCS are very sensitive to whether or not the sample weights are used; (*b*) much of the variation in published estimates of the MPC_f may be due to the use or lack of use of the NFCS sample weights rather than to more complex modeling and statistical issues.

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Expenditure Constraints and Profit Maximization in U.S. Agriculture: Comment

Barry T. Coyle

In a recent (1986) paper, Lee and Chambers (hereafter LC) developed a model of expenditure constrained profit maximization. A single constraint was specified for the purchase of all variable inputs, and the competing hypotheses of unconstrained and constrained profit maximization were tested in terms of corresponding nonnested homogeneity conditions. LC proceeded in terms of a profit function with prices normalized on the predetermined level of expenditure.

In this comment, an alternative formulation of the expenditure constrained profit function is presented. The advantages over the LC approach are twofold. First, the nested relationship between the hypotheses of unconstrained and expenditure-constrained profit maximization is apparent. This permits simple nested tests of the full consequences of the alternative models. Second, this alternative formulation can readily incorporate situations whereby expenditure constraints are input specific. For example, farmers typically negotiate separate loans for the purchases of operating inputs and capital inputs. Different expenditure constraints may have different impacts on incomes. Furthermore, input-specific foreign exchange constraints on production are easily incorporated into this formulation of the expenditure-constrained firm. The importance of modeling the effects of foreign exchange constraints on production in developing countries is well recognized (Dervis, de Melo, and Robinson); however, to date, econometric models of producer behavior have not incorporated the impacts of foreign exchange constraints in a consistent manner (e.g., Kohli, Diewert and Morrison).

Theoretical Background

We begin with a formulation of the expenditure constrained profit function that is similar to LC:

$$(1) \qquad \pi^o(p^o, w^o, E) = \max_{(x,y)\epsilon T} p^o y - w^o x \quad \text{s.t. } w^o x \leq E,$$

where $y = (y^1, \ldots, y^M)$ is a vector of outputs, $x = (x^1, \ldots, x^N)$ is a vector of variable inputs, p^o is an M-dimensional vector of output prices, w^o is an N-dimensional vector of variable input prices, T is the set of feasible (x, y), and E is the predetermined level of expenditure which the farmer cannot exceed in purchasing variable inputs. LC also assume a vector q of fixed inputs; but, in order to simplify notation, we will omit q from the list of arguments of the profit function.[1] LC observe that equilibrium input and output levels $x^* = x(p^o, w^o, E)$, $y^* = y(p^o, w^o, E)$ solving (1) are homogenous of degree zero in (p^o, w^o, E) and (if the expenditure constraint is binding) homogenous of degree zero in the vector of output prices p^o. This implies the following homogeneity restrictions on the profit function:

$$(2) \qquad \pi^o(\lambda p^o, \lambda w^o, \lambda E) = \lambda p^o y^* - \lambda w^o x^* = \lambda \pi^o(p^o, w^o, E),$$

and, if $w^o x^* = E$,

$$(3) \qquad \pi^o(\lambda p^o, w^o, E) = \lambda p^o y^* - w^o x^* = \lambda \pi^o(p^o, w^o, E) + (\lambda - 1)E,$$

where (x^*, y^*) denotes an equilibrium (x, y) at initial parameter levels (p^o, w^o, E), and λ is any positive scalar.

LC further impose the normalization $p = p^o/E$, $w = w^o/E$ and $\pi^o/E = \pi^o(p, w, 1)$ implied by (2). Analogous normalizations have been commonly employed in the specification of indirect utility functions, where there is little concern with testing hypotheses about the marginal utility of income (Christensen, Jorgenson, and Lau). However, in the producer case, this normalization obscures the nested relation between the hypotheses of constrained and unconstrained profit maximization.

In contrast we develop further properties of the profit function (1) without imposing this normalization. Expressing (1) in Lagrange form,

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[1] Weaker restrictions on technology are required in the case of an expenditure-constrained profit function than in the case of an unconstrained profit function. In particular, increasing returns to scale can be consistent with an expenditure-constrained equilibrium. By combining standard proofs of existence for a cost function (McFadden) and of equivalence of solutions to utility maximization and expenditure minimization problems (e.g., Varian), we can show that existence and continuity of the profit function are implied by the following assumptions:

$$V(y) = \{x: y^1 = f(y^2, \ldots, y^M, x); (x, y) \geq 0\}$$

is closed and nonempty; $f(\cdot)$ is continuous; and $P = \{(p^o, w^o, E)\}$ is compact. Differentiability of $\pi^o(p^o, w^o, E)$ can be established as in Blackorby and Diewert.

$$(4)\quad \pi^o(p^o, w^o, E) = \max_{\gamma,(x,y)\epsilon T} p^o y - w^o x + \gamma(E - w^o x),$$

and applying the envelope theorem yields

$$\partial\pi^o(p^o, w^o, E)/\partial p^{jo} = y^{j*} \qquad j = 1, \ldots, M;$$

$$\partial\pi^o(p^o, w^o, E)/\partial w^{io} = -x^{i*} - \gamma^* x^{i*}, \qquad i = 1, \ldots, N;$$

where $\gamma^* = \partial\pi^o(p^o, w^o, E)/\partial E$ (Takayama, pp. 137–39). Thus

$$(5)\quad y^j(p^o, w^o, E) = \partial\pi^o(p^o, w^o, E)/\partial p^{jo} \qquad j = 1, \ldots, M;$$

$$(6)\quad x^i(p^o, w^o, E) = \frac{-\partial\pi^o(p^o, w^o, E)/\partial w^{io}}{1 + \partial\pi^o(p^o, w^o, E)/\partial E} \qquad i = 1, \ldots, N.$$

These equations can be viewed as a generalization of Hotelling's lemma and Roy's identity. If the shadow price of the budget constraint, i.e., $\partial\pi^o(p^o, w^o, E)/\partial E$, is equal to zero, then these equations reduce to Hotelling's lemma. This occurs if the budget E is at the profit-maximizing level of expenditure.

The derivation of further restrictions on the Hessian matrix of second derivatives of the profit function is more complex. Suppose that the expenditure constraint $w^o x \leq E$ is satisfied as an equality and the profit function is twice differentiable. Define the gain function

$$(7)\quad g(p^o, w^o, x, y) = \pi^o(p^o, w^o, E(w^o, x)) - [p^o y - w^o x] \qquad (x, y)\epsilon T,$$

where $E(w^o, x) = w^o x$. It can be shown that $g(p^o, w^o, x, y)$ takes the minimum value of 0 when $(p^o, w^o, x, y) = (p^o, w^o, x^*, y^*)$ where $x^* = x(p^o, w^o, E)$ and $y^* = y(p^o, w^o, E)$ solve (1).[2] In turn, the $M + N$ dimensional matrix of second derivatives $g_{p^o w^o}(p^o, w^o, x^*, y^*)$ is symmetric positive semidefinite, i.e.,

$$(8)\quad d' g_{p^o w^o}(\cdot) d \geq 0 \qquad \text{for all } d$$

[Hatta, lemma 2 and equation (17)]. Using (7) the elements of this matrix are evaluated as follows:

$$(9)\quad \partial^2 g(p^o, w^o, x^*, y^*)/\partial p^{io}\partial p^{jo} = \partial^2\pi^o(p^o, w^o, E)/\partial p^{io}\partial p^{jo} \qquad i, j = 1, \ldots, M$$

$$\partial^2 g(p^o, w^o, x^*, y^*)/\partial p^{jo}\partial w^{io} = \partial^2\pi^o(p^o, w^o, E)/\partial p^{jo}\partial w^{io} + x^{i*}\partial^2\pi^o(p^o, w^o, E)/\partial p^{jo}\partial E \qquad i = 1, \ldots, N; j = 1, \ldots M$$

$$\partial^2 g(p^o, w^o, x^*, y^*)/\partial w^{io}\partial w^{jo} = \partial^2\pi^o(p^o, w^o, E)/\partial w^{io}\partial w^{jo} + x^{j*}\partial^2\pi^o(p^o, w^o, E)/\partial w^{io}\partial E + x^{i*}\partial^2\pi^o(p^o, w^o, E)/\partial w^{jo}\partial E + x^{i*}x^{j*}\partial^2\pi^o(p^o, w^o, E)/\partial E^2 \qquad i, j = 1, \ldots, N.$$

Equations (5)–(6) suggest the following procedure for estimating a producer's output supply and factor demand equations when there is an exogenous expenditure constraint as in model (1). First, specify an appropriate flexible functional form for the producer's profit function $\pi^o(p^o, w^o, E)$. Second, differentiate this functional form with respect to prices p^o, w^o and budget E in order to obtain output supply and factor demand equations, as indicated in (5)–(6). Third, estimate this system of equations and test or check whether these equations satisfy the restrictions listed above. Imposing appropriate homogeneity and symmetry restrictions on the model will increase efficiency of the estimators.

A model of unconstrained profit maximization is easily embedded within this model of expenditure constrained profit maximization. The standard competitive profit maximization problem of the firm can be defined as

$$\pi^o(p^o, w^o) = \max_{(x,y)\epsilon T} p^o y - w^o x,$$

or, equivalently,

$$(10)\quad \pi^o(p^o, w^o) = \max_{E\geq o} \pi^o(p^o, w^o, E).$$

In other words, unconstrained profit maximization can be decomposed logically into two stages: first profits are maximized for given levels of expenditure E (problem 1); and then the level of expenditure E is chosen so as to maximize profits (problem 10). This two-stage procedure is equivalent to unconstrained profit maximization.

Thus, profit maximization when total expenditure E is unconstrained implies the same restrictions on $\pi^o(p^o, w^o, E)$ as indicated above plus the first- and second-order conditions for an interior solution to (10):

$$(11)\quad \partial\pi^o(p^o, w^o, E)/\partial E = 0$$

$$(12)\quad \partial^2\pi^o(p^o, w^o, E)/\partial E^2 \leq 0.$$

This characterization of the standard maximization problem in terms of the expenditure constrained profit function $\pi^o(p^o, w^o, E)$ leads to relatively simple procedures for testing the hypothesis that expenditure on inputs is unconstrained.[3]

The above analysis is easily generalized to characterize particular cases where expenditure constraints are input specific. For example, suppose that expenditures on inputs $x^B = (x^{1B}, \ldots, x^{NB})$ draw upon

[2] The envelope relations (5)–(6) can also be derived directly from this property of the gain function (7) (Hatta, theorem 5).

[3] The basic implication of this nested relation $\pi^o(p^o, w^o) = \max_E \pi^o(p^o, w^o, E)$ for testing the hypothesis of unconstrained profit maximization is not discussed in Lee and Chambers (1986) nor in the comments by Färe and Sawyer, Lee and Chambers (1988).

an exogenous budget or credit constraint E, whereas expenditures on other inputs $x^A = (x^{1A}, \ldots, x^{NA})$ are unconstrained. Alternatively, inputs x^B may be imports drawing upon the firm's ration of foreign exchange E. The corresponding profit function $\pi^o(p^o, w^o, E)$ is now defined as

$$\pi^o(p^o, w^o, E) = \max_{(x,y)\epsilon T} p^o y - w^{Ao}x^A - w^{Bo}x^B \quad \text{s.t. } w^{Bo}x^B \leq E.$$

Applying the envelope theorem to the corresponding Lagrange function, equations (5)–(6) are modified as follows:

$$y^k(p^o, w^o, E) = \partial\pi^o(p^o, w^o, E)/\partial p^{ko} \quad k = 1, \ldots, M$$

$$x^i(p^o, w^o, E) = -\partial\pi^o(p^o, w^o, E)/\partial w^{io} \quad i = 1A, \ldots, NA$$

$$x^j(p^o, w^o, E) = \frac{-\partial\pi^o(p^o, w^o, E)/\partial w^{jo}}{1 + \partial\pi^o(p^o, w^o, E)/\partial E} \quad j = 1B, \ldots, NB.$$

In order to derive restrictions on $\pi(\cdot)$ that are analogous to (8)–(9), define the gain function

$$h(p^o, w^o, x, y) = \pi^o(p^o, w^{Ao}, w^{Bo}, E(w^{Bo}, x^B)) - [p^o y - w^o x] \quad (x, y)\epsilon T,$$

where $E(w^{Bo}, x^B) = w^{Bo}x^B$. Then the Hessian matrix $h_{p^o w^o}(p^o, w^o, x^*, y^*)$ is symmetric positive semidefinite (Hatta), where derivatives are evaluated in a manner analogous to (9). The nested relations (10)–(12) between constrained and unconstrained profit maximizaton models still apply in this case. The analysis can also be generalized in an obvious manner to cases of multiple expenditure constraints $w^{Ao}x^A \leq E^A$, $w^{Bo}x^B \leq E^B$.[4]

Functional Forms

In choosing appropriate functional forms for empirical models of expenditure constrained producer behavior, the constrained profit function $\pi^o(p^o, w^o, E)$ as in (1) must satisfy both homogeneity conditions (2) and (3).

In the case of a single output, substitution of $\lambda = 1/p^o$ into (3) yields the following restriction on functional forms for $\pi^o(p^o, w^o, E)$:[5]

$$\pi^o(p^o, w^o, E) = p^o\pi^o(1, w^o, E) + (p^o - 1)E = p^o\phi(w^o, E) + (p^o - 1)E.$$

The additional homogeneity condition (2) implies that the profit function can be expressed equivalently in the following normalized form:

$$\pi^* = \pi^*(p^*, w^*, E^*),$$

where $\pi^* \equiv \pi^o/w^{1o}$, $p^* \equiv p^o/w^{1o}$, $w^* \equiv (w^{2o}/w^{1o}, \ldots, w^{No}/w^{1o})$, $E^* \equiv E/w^{1o}$. Imposing homogeneity condition (3) on this normalized profit function,

$$\begin{aligned}\pi^*(p^*, w^*, E^*) &= \pi^o(p^*, 1, w^*, E^*) && \text{by (2)}\\ &= p^*\pi^o(1, 1, w^*, E^*) + (p^* - 1)E^* && \text{by (3)}\\ &= p^*\phi^*(w^*, E^*) + (p^* - 1)E^*.\end{aligned}$$

In the case of multiple outputs, the following class of functional forms for $\pi^o(p^o, w^o, E)$ satisfy homogeneity conditions (2) and (3):

$$\pi^*(p^*, w^*, E^*) = h(p^*)\phi^*(w^*, E^*) + [h(p^*) - 1]E^*$$

where $h(p^*)$ is linear homogenous in p^*.

The following variation on a normalized quadratic profit function with a single output satisfies these conditions:

$$\pi^* = p^*\left(a_o + \sum_{i=2}^{N} a_i w^{*i} + a_e E^* + \frac{1}{2}\sum_{i=2}^{N}\sum_{j=2}^{N} a_{ij}w^{*i}w^{*j} + \sum_{i=2}^{N} a_{ie}w^{*i}E^* + a_{ee}E^{*2}\right) + (p^* - 1)E^*.$$

This implies the output supply and factor demand equations, using (5)–(6),

$$\begin{aligned}y &= \phi^*(w^*, E^*) + E^*\\ &= a_o + \Sigma_i a_i w^{*i} + (a_e + 1)E^* + 1/2\Sigma_i\Sigma_j a_{ij}w^{*i}w^{*j} + \Sigma_i a_{ie}w^{*i}E^* + 1/2a_{ee}E^{*2}\end{aligned}$$

$$\begin{aligned}-x^i &= \frac{\partial\phi^*(w^*, E^*)/\partial w^{*i}}{1 + \partial\phi^*(w^*, E^*)/\partial E^*} \quad i = 2, \ldots, N.\\ &= \frac{a_i + \Sigma_j a_{ij}w^{*j} + a_{ie}E^*}{1 + a_e + \Sigma_i a_{ie}w^{*i} + a_{ee}E^*}\end{aligned}$$

Alternatively consider the following normalized translog profit function:

$$\log \pi^{**} = a_o + \sum_{i=1}^{N} a_i \log w^{**i} + a_e \log E^{**} + \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} a_{ij}\log w^{**i}\log w^{**j} + \sum_{i=1}^{N} a_{ie}\log w^{**i}\log E^{**} + \frac{1}{2}a_{ee}(\log E^{**})^2$$

[4] Lee and Chambers (1988) also note that the predetermined expenditure may be only a fraction (λ) of total expenditure. They suggest that their model be modified by treating E/λ rather than total observed expenditure E as exogenous expenditure, where λ is a parameter to be estimated. However, this ad hoc specification is inappropriate whenever the predetermined expenditure is associated with a specific subset of purchased inputs.

[5] Note that in the case ot a single output ($M = 1$) and $w^o x \leq E$ binding, expenditure-constrained maximization of profit reduces to expenditure-constrained maximization of output.

where $\pi^{**} \equiv \pi^o/p^o$, $w^{**} \equiv w^o/p^o$, $E^{**} \equiv E/p^o$. This satisfies both homogeneity conditions (2)–(3). Equations (6) imply the factor demand equations

$$-sx^j = \frac{a_j + \sum_{i=1}^{N} a_{ij} \log w^{**i} + a_{je} \log E^{**}}{1 + \left(a_e + \sum_{i=1}^{N} a_{ie} \log w^{**i} + a_{ee} \log E^{**}\right) \pi^o/E} \quad j = 1, \ldots, N,$$

where $sx^j \equiv w^{jo}x^j/\pi^o$.

Hypothesis Testing

This section illustrates two simple procedures for testing the hypothesis that expenditure on inputs is at profit-maximizing levels. The null hypothesis H_o is that expenditure E solves the unconstrained profit maximization problem $\max_{E \geq o} \pi^o(p^o, w^o, E)$, and the alternative hypothesis H_1 is that the firm is at an expenditure-constrained, profit-maximizing equilibrium. Given the nested relation between these hypotheses, an obvious approach is to test the first-order condition (11) for unconstrained profit maximization and then to check or test for the second-order condition (12) within the context of a particular specification for $\pi^o(p^o, w^o, E^o)$.

A t-test of the first-order condition (11) for unconstrained profit maximization can be formulated as follows from estimates of the system of output supply and input demand equations (5)–(6). Assuming normally distributed disturbances the statistic

$$(13) \qquad t_o \equiv \pi_E^*/V(\pi_E^*)^{1/2}$$

has a t-distribution under H_o, where π_E^* denotes the estimate of the shadow price. Linear approximations to the variance of the estimates π_E^* can be calculated essentially as in Kulatilaka. Suppose that the profit function $\pi^o(p^o, w^o, E)$ has a functional form of the type $\pi^o = f(p^o, w^o, E, \beta) + \epsilon$, as in the generalized Leontief or normalized quadratic case. Then $\pi_E^* = \partial f(p^o, w^o, E, \beta^*)/\partial E$, and in turn the variance of π_E^* can be approximated linearly as

$$(14) \qquad V(\pi_E^*) = \pi_{E\beta}^* V(\beta^*) \pi_{E\beta}^*,$$

where $\pi_{E\beta} \equiv \partial^2 f/\partial E \partial \beta$. Thus, given a normalized quadratic or generalized Leontief functional form for $\pi^o(p^o, w^o, E)$, the t-statistic t_o can be approximated directly from the estimates of output supply and factor demand equations (5)–(6). In the translog case, calculation of t_o would require direct estimation of the profit equation (Kulatilaka).

Alternatively a Hausman specification test can often be constructed for the first-order condition $\partial \pi^o(p^o, w^o, E)/\partial E = 0$ (11). Let $\hat{\beta}_1$ denote estimates of the coefficients of equations (5)–(6) obtained by three-stage least squares estimation of (5)–(6) alone, and let $\hat{\beta}_o$ denote estimates of the same coefficients obtained by three-stage least squares estimation of (5)–(6) plus (11). At the industry level, output prices p^o as well as expenditure E generally should be treated as endogenous. Then under the hypothesis H_o of unconstrained profit maximization, the following statistic is distributed asymptotically as chi-square:

$$(15) \qquad m \equiv (\hat{\beta}_1 - \hat{\beta}_o)\hat{V}^{-1}(\hat{\beta}_1 - \hat{\beta}_o),$$

where the variance-covariance matrix $\hat{V}$ is calculated as $\hat{V} = \hat{V}(\hat{\beta}_1) - \hat{V}(\hat{\beta}_o)$ (Hausman, Schankerman and Nadiri).

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International Financial Markets and Agricultural Adjustment in North America (G. Edward Schuh, Humphrey Institute of Public Affairs, presiding)

Exchange Rate Effects on Inputs and Outputs in Canadian Agriculture

Colin A. Carter, Richard S. Gray, and W. H. Furtan

In a seminal piece of work, Schuh demonstrates, using a single market partial equilibrium model, that exchange rates have a large impact on the price received for farm products. He argued that the overvalued U.S. dollar reduced export demand and the domestic price of U.S. grains. Since then, much of the work on estimating the impact of exchange rate changes on agriculture has implicitly assumed that inputs to the agricultural sector come from the nontraded sector.[1] We argue this assumption can result in an error in the estimation of the effects of exchange rates. In an examination of the pass-through of changes in the $US/CDN exchange rate, we find the data from 1975 to 1989 are consistent with the hypothesis of a complete pass-through of exchange rates for many important variable inputs to Canadian agricultural production. This analysis indicates that, while exchange rates may have had significant impacts on the return to fixed factors and farm income, they have had little effect on grain production. In the case of livestock feeding in Canada, exchange rate devaluations may actually reduce production and reduce the return to fixed factors because inputs (especially grain) are more tradeable than outputs. Finally, we examine the potential welfare impact on nontradeables (such as land) from changes in the exchange rate.

Theoretical Model

The framework in which to analyze the aggregate effects of exchange rates has been developed by Salter. In the Salter model goods in the economy are aggregated into two sectors, tradeable and nontradeable. The economy can produce different combinations of the two types of goods, given available technology and resources. The production possibilities can be represented by a concave hull *AB* as shown in figure 1. The economy also has a defined set of preferences over these goods which can be represented by a set of convex indifference curves, $u_1, u_2, \ldots, u_n$. The tangent of the indifference curve and the production possibility curve, i.e., point *C*, represents the equilibrium in the economy where the balance of trade requirement is met and where there is zero excess demand for nontradeables. The real exchange rate (or the ratio at which these conditions are met) is represented by the slope of line *RR*′. A change in exchange rates moves this point of tangency. A devaluation in the exchange rates means an increase in the nominal and real prices in the tradeable sector. This increases production in the tradeable sector.

Within the parameters derived in this general equilibrium setting it is possible to examine the effects of exchange rate changes on small specific industries using a simple model of the firm and partial equilibrium analysis. First, we assume exchange rates are set exogenously to the sector.[2] Second, we assume the two countries

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[1] Recognizing the importance of traded inputs, Carter and Hamilton estimate the impact a change in the Canada–U.S. exchange rate would have on the price of farm inputs used in Canadian wheat production.

[2] Rausser et al. argue the assumption of exogenously determined exchange rates is inappropriate for agriculture. This would rule out the use of partial equilibrium analysis. However, because agriculture in the United States and Canada is a very small part of the overall economy and accounts for a small part of total exports, the exogeneity assumption is considered appropriate. In addition, we are examining subsectors (e.g., wheat, livestock) within agriculture, and the exchange rate is truly exogenous to these subsectors.

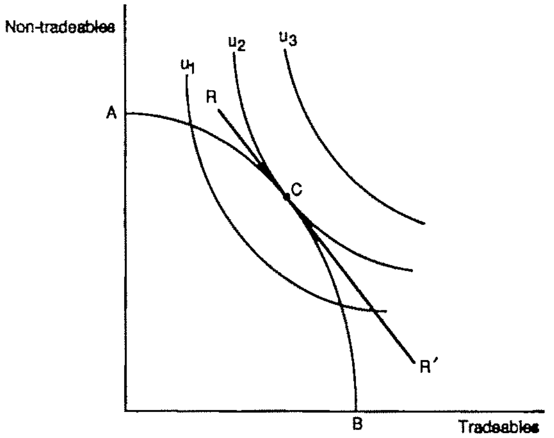

Figure 1. Real exchange rates in the Salter general equilibrium model

are both large countries (i.e., both countries impact on world prices). Lindert develops a similar model for the small country case. Finally, we do not incorporate any imperfect competition arguments.[3]

In figure 2, Country 1 (Canada) is the exporting region, while Country 2 (United States) is the importing region. The excess supply from Country 1 and excess demand from Country 2 are shown in panel b of figure 2—the international market. Initially the exchange rate between the two countries is par (shown in panel c of fig. 2 as the 45° line OA). The volume of trade is initially equal to OQ (shown in panel b).

The excess supply and demand condition for commodity i can be written

$$D_i = g(P_i) \tag{1}$$

$$S_i = \mathrm{h}(\delta_i, r) \tag{2}$$

$$D_i = S_i, \tag{3}$$

where r is a vector of input prices, P_i and δ_i are the output prices in each country's domestic currency.

If e is the exchange rate (units of the exporter's currency per unit of the importer's currency), the law of one price states: $e{*}P_i = \delta_i$. For a more complete analysis of the equilibrium conditions see Chambers and Just. If a change in e causes the value of the importer's currency to appreciate such that OA rotates to OA' in figure 2(c), the excess demand curve rotates upward from ED to ED' in figure 2(b). This results in an expansion of trade by an amount equal to QQ_1 as well as an increase in the exporter's price by an amount equal to PP_1. Chambers and Just argue that if the exchange rate also changes the price of substitute goods this would reduce the effect of the exchange rate on the demand for good i.

Inputs may also be traded. If Country 1 is assumed to import at least some inputs from Country 2, the excess supply curve will rotate from ES to ES' in figure 2(b) with an appreciation of Country 2's currency (e.g., Canada imports agriculture inputs from the United States, such as machinery and agriculture chemicals). This increased cost of production in the exporting country (Country 1) reduces the volume traded between the two countries and raises the commodity price from OP_1 to OP_2. The magnitude of the net change in trade and price depends upon the elasticity of excess demand and

[3] Others (Giovannini and Feenstra) have explored exchange rate pass-through using imperfect competition models.

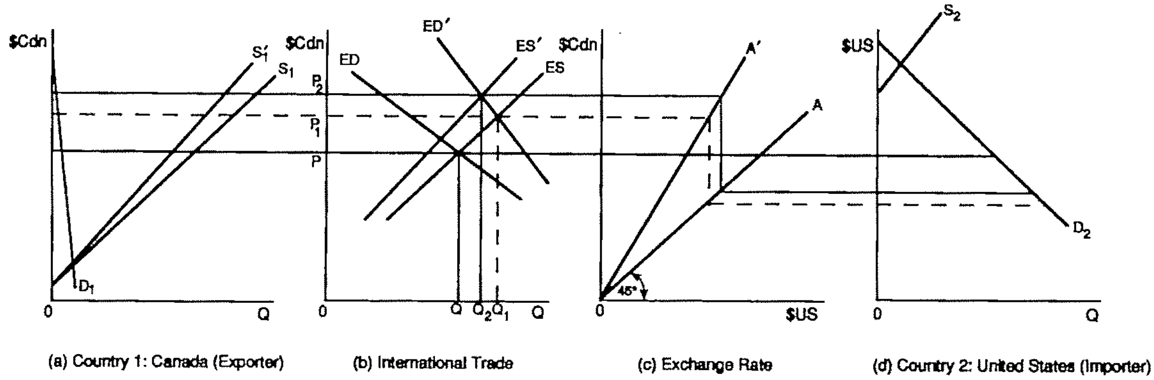

Figure 2. Exchange rate pass-through in a partial equilibrium model

supply and the proportion of traded inputs in total cost of production.

The welfare impacts in the exporting country may be large even though there is little change in the volume traded. As shown in figure 3, because of the increased cost of production (due to traded inputs), there may be little increase in commodity trade but a substantial gain in welfare in the exporting country. This results from an increase in the rent earned by those inputs which are not traded but used in the production of the exported commodity. In the case of agriculture, such inputs include land and labor. Producers in the exporting country gain area P_3deP_1 (fig. 3) and lose area *eba*, which may/may not represent a welfare increase depending upon the elasticity of the excess supply curve. The less elastic the excess supply, the greater the likelihood of producer gains. The volume traded may be unrelated to the welfare gains for the exporting country. Much of the analysis on exchange rates and agricultural trade between developed countries has focused on the volume of trade and price, ignoring these important welfare impacts.

Estimating Exchange Rate Pass-Through

An examination of exchange rate pass-through is one way of measuring whether or not inputs and outputs are tradeable. The estimation of the exchange rate pass-through has focused on the law of one price. The law of one price states that, in the presence of market arbitrage, the price of the same good in two locations will differ

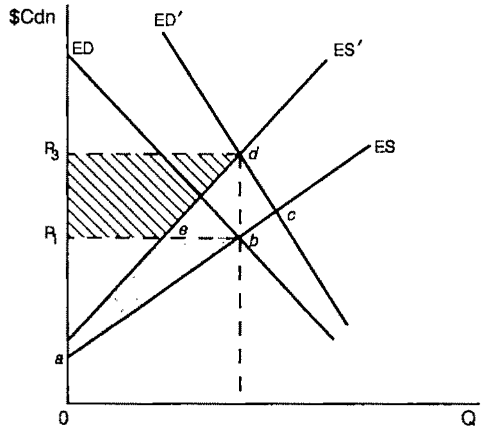

Figure 3. Welfare effects of an exchange rate depreciation

only by the transaction cost in moving the commodity from one market to another.

The law of one price is derived from the no arbitrage condition. The no arbitrage condition be written as

$$P_t^1 = P_t^2 e + \Phi, \tag{4a}$$

where P_t^1 and P_t^2 are the commodity prices, Φ is equal to the anticipated transaction cost in moving from market 2 to market 1, and e is the exchange rate.[4] Alternatively, equation (4a) can be written as

$$P_t^1/P_t^2 = e \cdot \Phi \tag{4b}$$

when Φ is proportional to the value of the products. The transaction cost Φ is made up factors including the direction of trade flows, transportation, storage, interest, tariffs, and a normal rate of return to the arbitrager. Because data on transaction costs are difficult to obtain, most studies ignore these costs and estimate the following equation:

$$P_t^1/P_t^2 = e \cdot \Phi + \epsilon. \tag{5}$$

Ardeni suggests that this type of behavior is consistent with the law of one price, which states that, in the long run, commodity prices in two countries must be the same. In his analysis he finds the law of one price fails as a long-run relationship, and deviations from the pattern are permanent.

This rejection of the law of one price in the long run may result from the omission of transaction costs in the analysis. An implicit assumption in equation (5) is that transaction costs were stationary and varied about some underlying mean over time. However, one would expect that, in the long run, transaction costs will change in a permanent fashion. Changes in income, tastes, technologies, and trade flows all tend to be permanent phenomena. Given the permanent nature of the shocks which effect transaction costs, it may be reasonable to assume that transaction costs vary over time in the following fashion:

$$\Phi_t = \Phi_{t-1}(1 + \gamma), \tag{6}$$

where γ is a random variable with mean μ and some variance σ.

If these innovations arrive in a continuous

[4] This pure relationship holds for a trade flow in a specific direction. If the trade flow direction changes, the sign of Φ would also change. There will also be a range of relative prices in which no trade will take place.

fashion, then by the central limit theorem the proportional change in transaction costs is lognormally distributed. Given this specification for the stochastic process, then first differencing equation (5) yields the estimating equations:

$$(7)\quad \ln\frac{P_t^1}{P_t^2} - \ln\frac{P_{t-1}^1}{P_{t-1}^2} = \ln e_t - \ln e_{t-1} + \ln\Phi_t - \ln\Phi_{t-1},$$

$$(8)\quad \ln\frac{P_t^1}{P_t^2} - \ln\frac{P_{t-1}^1}{P_{t-1}^2} = \ln\left(\frac{e_t}{e_{t-1}}\right) + \mu + \ln z,\ \ln z \sim N(0, \sigma^2),$$

$$(9)\quad \ln\frac{P_t^1}{P_t^2} - \ln\frac{P_{t-1}^1}{P_{t-1}^2} = \beta_0 + \beta_1 \ln\left(\frac{e_t}{e_{t-1}}\right) + \epsilon.$$

If $\beta_1 = 1$, then there is complete exchange rate pass-through. If β_1 does not equal 1.0, then the transaction cost must be a function of the exchange rate, which means there are sticky prices for some institutional reasons. For example, one such institution in agriculture would be a stabilization program complete with border controls. If prices are sticky, it is important to examine the period of time for which they are sticky. Unless prices were changed on a daily basis, one would expect some lag time to fully reflect unanticipated changes in exchange rates. As Ardeni points out, in models employing first differences the error structure of the model is not fully specified. Thus, the rate at which the exchange rate changes are fully transmitted through to commodity prices must be studied. This can be done within this framework by adding lagged exchange rates to the regression analysis to capture the lagged effect of exchange rates on prices. the more general model to estimate is of the form:

$$(10)\quad \ln\frac{P_t^1}{P_t^2} - \ln\frac{P_{t-1}^1}{P_{t-1}^2} = \beta_0 + \beta_1 \ln\left(\frac{e_t}{e_{t-1}}\right) + \beta_2 \ln\left(\frac{e_{t-1}}{e_{t-2}}\right) + \beta_3 \ln\left(\frac{e_{t-2}}{e_{t-3}}\right) + \epsilon.$$

Data and Results

In order to estimate exchange rate pass-through for Canadian agriculture, equation (10) was estimated using ordinary least squares for three outputs and five inputs for Canadian and U.S. agriculture. The relative prices of wheat, oilseeds, and livestock were estimated using published quarterly average cash prices at a specific locations in each country. The relative prices of petroleum, fertilizer, pesticides, and machinery were calculated from aggregate farm input price indexes in each of the two countries. All regressions included data from 1975 to the second quarter of 1988 which, given the two quarter lagged variables, yielded fifty-two observations. Seasonal dummies were estimated for all of the equations but were significant only in the feeder cattle equation.

The results of the regressions are reported in table 1. In addition to the standard results, student t-values are reported for the tests that: (a) the contemporaneous quarter plus the two lagged effects sum to one, which is consistent with complete pass-through; and, alternatively, (b) the exchange rate elasticities sum to zero, which is consistent with no pass-through. The data strongly support a contemporaneous pass-through for wheat, canola, and petroleum, a one-quarter lagged pass-through for feeder steers, fat steers, and pesticides, and a two-quarter (3/4) lagged pass-through for fertilizer and no pass-through for farm machinery. Given these high pass-through rates on the major variable inputs in Canadian agricultural production, exchange rates should have had little effect on allocative decisions within the grain sector.

However, the beef sector is a different story. The immediate pass-through on grains and the one-quarter lag effect on fat prices should mean a reduction in the feeding margins when the Canadian dollar devalues. This relationship is consistent with a negative contemporaneous pass-through with respect to feeder prices. The increased feeding costs are reflected in a drop in the price of feeder steers. It is this industry which may be adversely affected by devaluations in the dollar.

The low R-squared in each of the equations indicates that exchange rate changes only explain a small part of the changes in the relative Canadian/U.S. prices. This result is not that unreasonable because exchange rate changes were rather small during the sample period. Exchange rates ($Cdn/$US) slowly increased during the period from a low of .97 near the beginning of the period to a high of 1.4.

Another interesting aspect of the data is the strong seasonal effect on pass-through in the price of feeder steers. The seasonal variable indicates that pass-through is much greater in the second and fourth quarters of the year than in the first and third quarter of the year. This seasonal pattern is consistent with the time of year feeders

Table 1. The Exchange Rate Pass-Through for Canadian Agricultural Inputs and Outputs

Commodity	β_0 (t)	β_{1t} (t)	β_{1t-1} (t)	β_{1t-2} (t)	F D-W	R^2 r: $\Sigma\beta = 1$	r: $\Sigma\beta = 0$
Wheat	0.0004	0.64	0.39	0.09	2.55	0.14	2.40
	(0.05)	(2.03)	(1.21)	(0.27)	1.80	0.27	
Canola/soya	0.0052	0.93	0.65	−0.15	2.08	0.12	1.89
	(0.52)	(1.82)	(1.25)	(0.27)	1.57	0.56	
Feeder steers	0.0064	0.14	0.46	0.63	0.94	0.06	1.60
	(0.62)	(0.27)	(0.88)	(1.12)	2.54	0.31	
Feeder steers	0.03	−0.22	1.0	0.28	3.04	0.29	1.51
(seasonally adjusted)	(1.67)	(0.46)	(2.02)	(0.54)	2.23	0.09	
	D_1	D_2	D_3				
	−0.063	0.022	−0.051				
	(2.51)	(0.90)	(2.01)				
Fat steers	0.0008	0.6	0.14	0.19	0.87	0.05	1.41
	(0.09)	(1.32)	(0.32)	(0.42)	2.53	0.08	
Fertilizer	0.005	−0.41	0.35	0.52	2.37	0.13	1.19
	(0.98)	(1.56)	(1.32)	(1.85)	2.05	1.38	
Pesticides	0.0055	0.133	0.31	0.565	4.14	0.20	3.36
	(1.39)	(0.65)	(1.51)	(2.57)	1.97	0.04	
Petroleum	0.0023	1.27	−0.33	−0.21	2.82	0.15	1.11
	(0.27)	(2.91)	(0.74)	(0.46)	2.12	0.42	
Machinery	0.0003	0.19	0.09	−0.17	0.99	0.06	.48
	(0.11)	(1.23)	(0.61)	(1.05)	2.20	3.9	

are actively traded. In the first quarter the calves are wintering on feed. In the second quarter they are being put on grass. In the third quarter they remain on pasture, and in the fourth quarter they come off the grass to be fed. Thus, one would expect a substantial trade in the animals only in the second or the fourth quarters of the year. The data support this seasonal pattern.

The lack of exchange rate pass-through on new machinery prices appears inconsistent with the lack of trade barriers and the relatively low transport costs for machinery. A reasonable explanation for this lack of pass-through is that a change in exchange rates is consistent with a difference in nominal interest rates in the two countries.[5] Thus, an increase in the exchange rate which lowers the purchase price of a new machine will be correlated with increases in the interest cost. Machinery dealers respond to the decreased demand for their product (and higher inventory costs) by lowering margins. The farmer is precluded from buying in the other country by the inability to have the machine serviced by the local dealer in the event of a breakdown. A similar, but somewhat weaker, story involves fertilizer markups. In this case the local dealer often provides service in terms of timely delivery and occasionally the rental of application equipment.

[5] Carter and Hamilton found a strong correlation between the change in exchange rate and nominal interest rates in Canada, which one would expect given arbitrage in financial markets.

Conclusions

This paper presents a framework for evaluating exchange rate effects when both inputs and outputs are tradeable. The impacts of exchange rates on input and output prices, volumes traded, and welfare were described. The important effect on input prices and welfare has been previously ignored in the literature.

Empirically, we found exchange rate pass-through on the major variable inputs used in Canadian agriculture to be significant. A difference occurs in the rate of pass-through that may be explained by institutional factors such as price pooling and localized dealer markups. A major conclusion is that the input prices as well as commodity prices are affected by exchange rates. This may reduce the short-run effect of exchange rates (in the case of wheat producers) or even reverse the impact (as in the case of feeder cattle).

Given the large pass-through on many of the variable inputs and outputs, the exchange rates will have a small impact on the quantity produced. Given the small production effect, rents or returns to fixed factors should change approximately in proportion to the change in exchange rates. Finally, the small production effect of exchange rates reduces the impact of agricultural trade in determining exchange rates. Under these conditions a partial equilibrium analysis is appropriate.

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Performance of Mexican Agriculture: The Effects of Economic and Agricultural Policies

Manuel R. Villa-Issa

Mexican agriculture is having difficulties for several reasons. Especially important was the need in 1989 to import 9.5 million tons of basic food, mainly corn, wheat sorghum, beans, and milk. Much needs to be done in order to return agriculture to a profitable activity.

In this paper I will analyze the relationship between macroeconomic factors, mainly foreign exchange, investment, and prices, and the performance of the farm sector. Three time periods are considered: (*a*) from 1910, when the Mexican Revolution started, to 1940 when agriculture began to exist in a peaceful environment; (*b*) from 1940 to 1970, when the agricultural growth rate surpassed the population increase, exports were in progress, and the farm sector was contributing effectively to the whole economy, although the conditions for a poor sector performance were developing; and (*c*) from 1970 to the present, when, as a result of past and current policy conditions, the rural sector moved to a point where it was unable to contribute as effectively to the economy. Food imports increased, trade was nearly balanced, and the strength of agriculture generally deteriorated.

The Period from 1910 to 1940

Early in this century, Mexico depended mostly on agriculture. More than 90% of the population was involved in agriculture. However, land was concentrated in a few hands. Before the 1910 Revolution, about 97% of the land in Mexico was owned by 830 people or corporations. Approximately 3.5 million peasants were landless.

During 1910 to 1930, internal war dominated the country. Many people left agriculture; whatever was produced was devoted to feed the fighting groups, and little investment in agriculture occurred. In general, capital outflow from the farm sector was mainly the result of social instability.

During the 1930s many agricultural policies were initiated to stimulate development in the farm sector. Land distribution began; credit, roads, irrigation developments, and research also began to appear in the sector. Agriculture production began to increase again from a very low point, at an increasing rate. This situation, thus, characterized the early 1940s.

During the late 1930s, conditions to foster further expansion of raw material exports and growth of consumer goods were created. Landowners' economic power was undermined, and agrarian reform widened the agricultural boundaries upon redistribution of 18.8 million hectares. For comparison purposes, consider that the annual average area under cultivation was less than 6 million hectares. In addition, the institutional framework aimed at facilitating economic expansion was created.

In 1934 (National Financiera was established in 1937) the National Foreign Trade Bank was founded; in 1938, the Tariff Act was passed, and in 1939 the New Industry Support Act was adopted. Other state-run companies created at that time that were vital for the economy were Pemex (the oil monopoly) and CFE (the Federal Electricity Commission). The financial system, which had deteriorated during the armed conflict, was given further strength. By 1940, credit had more than doubled compared to the 1925 level.

The Period from 1940 to 1970

This period is divided into two parts for better understanding: (*a*) 1940 to 1955 was a period of growth with inflation, and (*b*) 1955 to 1970 was a stabilizing development period.

At the end of World War II, the Mexican gov-

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ernment became involved in an industrial input substitution model in order to increase the rate of development. Because most of the international resources were devoted to the reconstruction of Europe, the main source to finance this model was the agricultural sector. Under this condition agriculture had to generate resources for its own development as well as industrial and commercial development.

The federal public investment, which in 1940 was 4% of the gross domestic product (GDP), increased to 5% by 1955. The investment structure was also modified in 1940: 52% was devoted to railways, roads, and bridge construction; 36% went to hydraulic works for the agricultural sector and industrial development.

The exchange rate was another policy instrument. Because the Mexican peso was overvalued at the beginning of World War II, substantial imports of intermediate and capital goods occurred. By 1955, the Mexican currency had a 33% overvaluation (equilibrium base 1950). Imports of goods were curbed by levying tariffs, permits, and duties.

Within this framework, the Mexican economy began to expand. Sustained growth was accompanied by relatively high inflation and exchange instability. The GDP increased at an annual rate of 6% in real terms. This growth came primarily from commercial manufacturing and the agricultural sector. These activities accounted for about 70% of the GDP growth rate in this period. Economic policy and agriculture in particular were successful: employment grew, income rose, and the nation began to improve its economic and social well being.

The agrarian reform substantially widened agricultural boundaries. The area under cultivation increased at an annual rate of 2.9%. Furthermore, 1.6 million hectares were added to the irrigation system, which represented 18% of the area under crop by 1955.

The agricultural trade balance recorded a surplus. From 1950 through 1955, the farm sector accounted for 54% of the overall exports while representing only 7.6% of imports. Although exports of agricultural products were encouraged by international demand, domestic policies, such as the exchange rate and the protection policy, had a negative effect ranging from −2% to −6% level, respectively. Under these circumstances, the resource transfers from the agricultural sector to the rest of the economy were estimated to average 1% of the agricultural GDP annually.

During this period relative prices in the internal market favored the agricultural sector. However, the relationship changed over time. The ratio of farm prices relative to the general index fell from 1.23 in 1940 to 0.93 in 1970. The price relationship between agriculture and industry fell from 1.18 in 1940 to 0.89 in 1970. This decline represents a real decrease of 25% in a thirty-year period.

The economic growth and the international trade recovery resulted in imports outgrowing exports in the early 1950s. The balance of trade deficit accounted for an average of 3.5% of the GDP on a five-year basis. Furthermore, in spite of long-term capital inflows, Banco de Mexico's (the Central Bank) international reserves shrank to a yearly average rate of 8% between 1950 and 1954. In view of balance-of-payment difficulties and a 10% annual inflation rate, the federal government decided to change its development strategy.

The new strategy gave rise to a "stabilizing development" period. It was based on urban-industrial expansion. Industrial growth was fostered by an import-substitution system encouraged by protective tariffs followed by quantitative controls on manufacturers, mainly durable consumer goods. Manufacturing industry grew at an annual real rate of 8.4%. The nondurable consumer industry was no longer the most dynamic, despite a real annual growth of 6.4%. It was replaced by the durable consumer goods industry, with an annual growth rate of 13%.

The exchange rate was fixed and currency conversions were free. The peso/dollar parity was contained at 12.50 from 1954 to 1976, involving a large peso overvaluation strategy to foster imports required in the industrial sector.

Economic policies aimed at backing urban-industrial development had a positive impact on the economy as a whole; however, the impact on agricultural sector development was negative and getting worse. Agricultural activities rose at 3% between 1955 and 1970. However, by 1965 agricultural output value trends declined. The farm sector's annual growth rate was 3.1% during the 1955–60 period, 5.8% during 1960–65, and 1.0% during 1965–72. By the end of the stabilizing development period, agricultural activities showed complete stagnation.

Following 1965, the Mexican farm sector no longer fulfilled certain key roles. The drop in foodstuffs and raw material output caused large imports of basic crops by the end of the stabilizing development period. A partial explanation for the change in farm sector performance is as follows.

In spite of the annual 4% increase in gross agricultural investments 1960–72, a substantial share (about 32% of gross investment) was devoted to maintenance and replacement of irrigation works carried out during the two previous decades. The pricing policy adopted was a negative one. Thus, from 1955 through 1972, farm prices lagged by 19% with respect to the implicit deflator. The drop in real prices as well as the increase in the cost of farm imports brought about by the closing of borders discouraged private investment in the rural sector. The response was increasing allocations of public funds.

In spite of the public sector's ever-increasing allocation of resources to farm activities, private investment was discouraged, mainly because of the sector's negative pricing policy and to the exchange rate policy. The exchange rate was overvalued by about 22% from 1954 through 1972. Between 1960 and 1972, public investment grew from 2.6% of the agricultural GDP to 8.6%, while private investment declined from 20.9% of the agricultural GDP to 17.7%.

Various interventions in the market had an overall negative effect on the farming sector. The net rates of nominal and effective protections for 1970 were minus 10.3% and minus 13.1%, respectively. On the one hand, prices received for domestic production were about 10% below international prices and, on the other hand, the sector experienced a 13% decline in value added relative to the absence of market interventions.

A strong contrast exists between the agricultural sector protection rates and those relative to durable consumer goods and capital goods. The latter were about 12.7% and 34.6%. In addition, the fertilizer and insecticide programs exhibited protection rates of 15.5% and 197.1%, respectively.

In summary during the first decde of the stabilizing development period, the farming sector fulfilled its role of supplies of foodstuffs and raw material. Subsequently—from 1965 to 1972—food supply became increasingly difficult, giving way to massive cereal imports.

During this period, the farm sector's capacity to provide net transfers of foreign currency to the rest of the economy gradually eroded. The trade balance surplus dropped by 1.1% annually. Agricultural exports maintained a 52% share of overall exports. Agricultural imports, on the other hand, increased relative to overall imports. By 1972 imports reached 10.1%, basically because of corn and wheat purchases abroad.

The Period from 1972 to 1986

The 1971 and 1972 years represent the end of the stabilizing development period and the beginning of a new economic policy. In 1971, the stabilizing development reached a turning point: GDP grew 3.4%, and per-capita product rose 1.7%, compared to previous annual rates of 7.2% and 3.7%, respectively. The slower growth was reflected by several indicators: gross investment fell by 5.1% (public investment diminished 26.6%), and domestic savings dropped 6%, the credit flow declined by 28.5%, and merchandise exports declined 3.1% (in spite of the rise in grain imports).

This situation forced the federal government to reorient the economic policy. In 1972, the government attempted to reactivate the economy through government expenditure and an increase in demand. Federal current expenditure rose by 22.9%, and capital expenditure increased 81.9%; banking credit grew 7.5%, and the money supply increased by 21.2%.

Industry, building, and mining (including oil) increased at annual rates of 7.2%, 8.3%, and 11.7%, respectively. The oil sector was the most active during the period and, together with mining, reached a share of 6.3% of the GDP in 1981, up from 2.1% in 1971. Modern manufacturing continued to expand compared to the traditional industrial activity, although the difference between those rates was less than during the stabilizing development period. Therefore, modern industry had a 53% share of the industrial GDP in 1981, up from 49% in 1972.

Such economic development, mainly in the oil sector, caused a greater need for capital good imports. Import substitution of durable goods essentially ended.

Imports were favored by an exchange policy that overvalued the exchange rate. From August 1970 to August 1976, the currency was overvalued by 13.4%. In 1976 the peso was devalued, but by December 1981, overvaluation (compared to September 1976) had reached 35.3%.

Imports recorded a real growth rate of 27.1% a year, and exports (mainly oil) grew 24.5% annually. The trade deficit accounted for a major part of the current account deficit, amounting to US$12,544.3 million in 1981. The current account deficit was offset by the capital account surplus, mainly long-term net capital of the public sector.

From 1972 to 1981 the farming sector benefited from the government expenditure policy.

Government gross investment in agriculture rose at a real annual rate of 13.1% and averaged 14.8% of agricultural GDP. Furthermore, it benefited from both the price control on products generated by the public sector and the subsidies policy. For example, the implicit price index increased by 478.8%, while the price of gasoline, farming tractors, and fertilizers grew by only 148.6%, 185.7%, and 171.5%, respectively. Subsidies through loans granted by agricultural trust funds (FIRA) were estimated at 0.2% of the agricultural GDP in 1975 and increased to 2.3% in 1981.

Other public investment also benefited the agricultural sector. Fertilizers and seed production, both concentrated in the public sector, increased 15.4% and 17.1% annually from 1972 to 1981.

On the other hand, price policy, although erratic throughout the period, had negative effects overall. Agricultural product prices deteriorated against the implicit price index by 3.4% from 1972 to 1982. In particular, the real price of corn and beans decreased 16.1% and 23.4%, respectively, in this period. The overvalued exchange rate policy resulted in the stagnation of agricultural exports and the fostered imports of consumer and capital goods.

In the 1970s, the growth rate of basic food (corn, beans, and wheat) production was lower than the population growth rate. Corn production increased at a 0.4% annual rate and beans and wheat grew at (−0.9) and 2.9% annually. Meanwhile, crops for livestock feed and edible vegetable oils reached high rates of growth. Sorghum, soybean, alfalfa, and safflower achieved annual rates of 9.4%, 11.3%, and 7.7% a year. This period was marked by increasing imports of agricultural food and raw material. Raw material imports increased as a result of the greater consumption of meat, eggs, milk, and vegetable oil by medium- and high-income consumers in the mid-1970s.

The sector's role as foreign currency supplier also slowed down. The balance-of-trade surplus decreased from 1972 to 1975. As mentioned above, this situation was influenced by the foreign exchange policy. After the 1976 devaluation, the surplus again grew until 1979. For the first time, the slight exchange rate flexibility during 1980–82 resulted in an agricultural trade deficit. Consequently, the agricultural sector's role as a foreign currency supplier came to an end in the last five-year period of the 1970s; it has been a net currency receiver since 1980.

Consider next the performance of the farm sector during the period 1982 to 1986, when economic policy was instituted mainly to control inflation, reduce the burden of foreign debt, and to avoid social unrest. This period was characterized by a decline in oil price, decreasing rates of public and private investment, and attempts to undervalue the exchange rate in order to stimulate exports.

During the early 1980s, aggregate demand accelerated because of the increase in the government expenditure based on income from oil exports. It reached \$US9.4 billion in 1980 compared to \$US3.8 billion in 1979. This situation resulted in an increase of real subsidies because this mechanism was used to partially transfer the oil resources to the rest of the economy. Furthermore, government expenditure was backed by a larger indebtedness.

Unfortunately, a foreign exchange policy holding the proper relationship between the spread of internal and external prices and the difference between inflation in Mexico and that of its trading partners was not implemented. The peso overvaluation was sustained, estimated at 35.5% by December 1981 compared to September 1976, when the last devaluation occurred. The result was a stagnation of nonoil exports and an acceleration of imports of luxury consumer goods that had a little impact on economic growth. Tourism, too, experienced drastic income reduction because of the peso overvaluation.

In short, at the beginning of 1982, the country's economic and financial situation was unfavorable: strong inflationary pressures on the supply and the demand side, a drastic reduction in government revenues, the lagging of public sector prices and tariffs, and the burden of debt servicing. The effect of the problems outlined above was felt in economic activity: GDP decreased by 0.5% in 1982, and none of the sectors recorded a higher growth than the previous year. Gross fixed investment dropped almost 16%.

The agricultural situation was not different from the rest of the economy and was aggravated in 1982 by an unusual drought. The favorable performance of agriculture in 1980 and 1981, strongly supported by subsidies from the SAM, became a serious decline in 1982: agricultural GDP fell 2.9%, and gross fixed investment declined 16.8%; cultivated land diminished 14.6%, and the average agricultural wage decreased 3.8%. The sharp decline in agricultural imports, −54.6%, exceeded the 16.7% drop of exports resulting in a positive trade balance.

The agricultural sector had an adequate per-

formance in 1983. Agricultural GDP rose 4.1%, cultivated land increased 17%, and production increased 4.2%. Balance of trade recorded a deficit of $US452 million, mainly because of import growth (54.7%). Exporters could not benefit from undervaluation (−30.7% from February 1982 to December 1983) because of the impact of the 1982 drought on the autumn-winter export crops harvested at the beginning of 1983. Therefore, agricultural exports grew only 1.2%.

The deficit reduction policy meant lower subsidies for the agricultural sector, and the exchange policy (undervaluation) increased production costs. The public sector adjusted guarantee prices to counterbalance rising costs (132%); however, this adjustment did not offset inflation because the real price fall was 7.4%. Nevertheless, guarantee price deterioration slowed compared to the 16.8% drop in 1982. In 1984, the agricultural GDP reached a growth rate of 2.6%, despite the bad weather. Cultivated land diminished 2%, but production increased 2.5%. Exports increased 17% in response to undervaluation. The decline in grain and forage production resulted in an increase of imports by 10.5%.

Going back to the policy of subsidies reduction, agricultural output costs continued increasing in real terms. Guaranteed prices were increased over the costs rate in order to offset the negative impact on this sector. Thus, guaranteed prices rose 21% above raw material costs, 22% in real terms.

In 1985, the area under cultivation increased by 2.6%. Wheat crops grew at 16.0% compared to the previous year. Sorghum, rice, and corn had high growth rates as well. The large availability of these and other products because of good weather conditions substantially reduced imports (14.5%), while exports declined 3.5%. Thus, the agricultural trade deficit declined from US$419 million in 1984 to US$197 million in 1985. Compared to the previous year, the growth rate of guarantee prices exceeded the inflation implicit index (3.6%), and the price policy was favorable because prices rose above production costs.

Bad weather conditions and drought prevailed in 1986, completely damaging 500 thousand hectares. Output in the agricultural sector drastically fell (4.2%). Cultivated land diminished by 8%. Sorghum and corn output declined by 65% and 14%, respectively. Storage water declined by 44% compared to the previous year. Fertilizers, in the form of nitrogen, phosphorus, and potassium products diminished by 9.3%, 8.8%, and 2.2%, respectively. Besides weather conditions, agriculture was seriously affected by the resulting negative price policy. Input costs increased 17% above the increase in guarantee prices, resulting in a substantial drop in the sector's profitability. Nonetheless, a combination of increases in exports and a decline in imports caused the previous year's trade deficit (US$197 million), to become a surplus of over US$1 billion. This year is a good example of the way exports may be fostered despite an adverse economic atmosphere and unfavorable weather conditions.

Concluding Comments

An important thrust of the argument in this paper is that farm sector performance depends a great deal on policy decisions taken outside the sector. Policies focusing on exchange rates, investment for the economy and for the rural sector, and product and input prices explain much of the sector's performance. The Mexican case is a good example, especially for the post-World War II era, when the farm sector was powerful and could fulfill its role in the economy. Since World War II, the economy essentially followed an industrial-urban development model and economic forces tended to move against the farm sector.

As development occurs, the relative importance of the rural sector is expected to decline; however, this does not imply economic stagnation in agriculture. On the contrary, the smaller the sector over time, the stronger it must be.

The challenge for the future is to better coordinate agricultural and macroeconomic policies. Much research is needed to understand what the key relationships are for making the right decisions.

International Capital Markets and Structural Adjustment in U.S. Agriculture

David Orden

The problem of foreign investments, or more generally of international movements of capital, has come very much to the fore during the last few years. Financial and general economic interests of the widest bearing are intimately connected with this problem . . . and the whole subject is more and more drawn both into the internal political controversies of the various countries and into the sphere of international discussion.

—Gustav Cassel, June 1928

Sixty-one years after Professor Cassel addressed the Harris Foundation about problems of trade and foreign investments, we again find international capital movements at the center of international trade discussions. The objectives of this paper are to place recent experience—in which the effects of trade and capital flows on agriculture have been widely recognized—in historical context and to draw on this review to offer some conclusions about the current U.S. trade deficits and agriculture.

International Capital Movements: 1900–88

Figure 1 presents data that places the recent prominence of international capital movements in perspective. U.S. international debt near the turn of the century (1897) is estimated to have approached 18.0% of annual national output. Over the next seventeen years, the United States maintained a positive balance on merchandise trade, with exports averaging 6.5% of gross national product (GNP). Still, we remained a debtor nation (around 6% of GNP) on the eve of World War I.

During the war, exports rose to almost 11% of GNP, and the trade surplus to about 5%. Europeans drew down their foreign investments and the United States emerged as a major international creditor. Private loans to the Allies amounted to $2.5 billion (about equal in value to our net pre-war debt), and the U.S. Treasury extended additional credit of $9.4 billion.

Emergence as a creditor nation shifted the international flow of investment income across the U.S. border. Prior to 1914, net annual payments to foreign investors had been on the order of $50–$100 million (0.2% of GNP). By 1919, income on private U.S. investments abroad exceeded income on foreign investments in the United States by 0.5% of GNP. Thus, the United States could have sustained substantial trade deficits during the 1920s. However, while exports fell to less than 6% of GNP, the United States remained a net exporter by making large private transfers and providing extensive new loans.

Following the stock market crash in 1929, both American invesetments abroad and foreign investments in the United States were reduced. World income and trade collapsed during the depression, but the net creditor status of the United States rose to almost 20% of GNP, a complete reversal of the situation at the turn of the century. Subsequently, as war approached, U.S. and foreign capital moved out of Europe. This capital movement again could have been associated with U.S. trade deficits, but was not, as official reserve asset accumulation more than offset other capital flows.

During the second world war, a large trade surplus was financed by transfers instead of loans. The war is then followed by a long period of relative calm in international capital and goods markets. The values of private investments abroad and foreign investments in the United States both grew at about the rate of nominal GNP through

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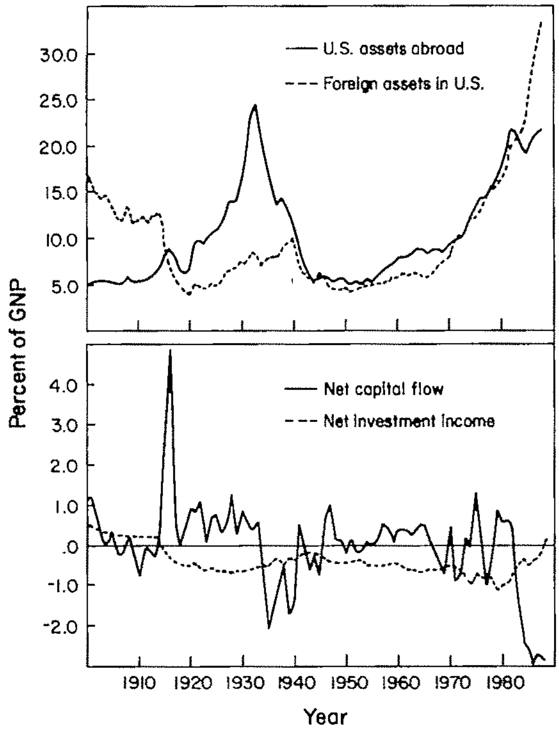


Figure 1. Stock of private U.S. assets abroad and foreign assets in the United States and net annual capital flows and investment income, as a percent of GNP, 1900–88

1970, and exports fell below 4% of GNP in the 1950s and 1960s. The net value of international asset holdings (U.S. private investments abroad minus foreign investments in the U.S.) remained less the 2% of GNP throughout this period.

After the devaluation and floating of the dollar in the early 1970s, there is a reemergence of international capital markets. This reemergence has been cited by Schuh and others as a crucial development affecting U.S. agriculture. Capital outflows from the United States increased almost sevenfold in a decade, and exports (total) again reached 6.5% of GNP. Foreign investments in the United States matched the rapid increase in our investments abroad. For the first time during this century, the United States sustained a significant trade deficit, more than offset until 1980 by a positive balance-of-investment income.

Since 1980, private capital outflows have collapsed, and the stock of U.S. investments abroad has stagnated. Foreign capital inflows have continually grown, and the United States is a debtor nation for the first time in seventy years. The change in direction of net capital flows of almost 3.5% of GNP during 1981–83 was larger than at any time except during World War I, and U.S. net debt is now around 10% of annual output.

Agricultural Prosperity and Collapse: 1910–29

Further perspective on the impact of international capital markets on agriculture comes from an examination of the policy debates and economic adjustments that occurred during the period 1910–29, when the United States first emerged as a major world creditor. Particularly relevant are the effects of investment income and new capital flows on agricultural exports and the emergence of postwar agricutural policy in the context of monetary policy, tariff policy, and war-debt policies that generally discriminated against agriculture.

To set the stage for this discussion, one needs to remember that the agricultural sector was relatively prosperous in the period before World War I (Hansen). The export-oriented war economy then created both real growth and inflation. Nominal net farm income rose from a 1912–14 average of $4.1 billion to $8.9 billion in 1918. Prices received by farmers for crops and livestock rose 102.2% and 79.4%, respectively, and the parity index rose from 99 to 120.

The armistice in late 1918 created uncertainty about the economic expansion, export markets, and prices. Stimulative fiscal deficits continued through 1919, and the Federal Reserve Board deferred a contraction of domestic credit to allow the treasury to float its last war bond issue at low interest rates (Crabbe)—a sort of unpleasant monetarist arithmetic. These monetary and fiscal policies were particularly effective with respect to agriculture. The nominal value of agricultural exports rose 57% in 1919, and farm income rose to $9.1 billion, although the parity index fell to 110.

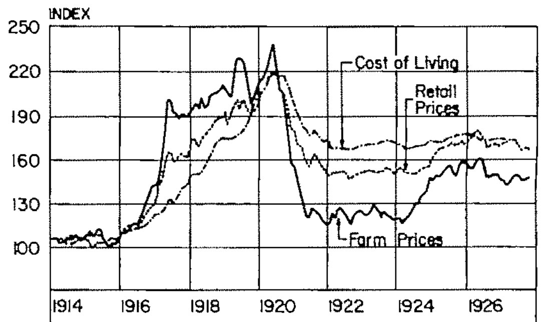
The postwar boom was also short lived. Nominal GNP dropped by almost one-quarter during 1920–21 and real GNP fell 8%. The parity index fell below 80 as prices received for crops dropped 41% during the second half of 1920. Possibly this was the worst collapse yet experienced by American farmers, and throughout the rest of the decade agriculture remained depressed relative to the nonfarm economy (Benedict).

Policy Issues

At the end of World War I, farmers and agricultural statesman shared the general uncertainty about the prospects for maintaining peacetime prosperity. G. E. Warren focused his January 1919 address to the American Farm Management Association on programs for making farm life more attractive. He asserted that food was "almost certain to continue to call for a larger share of the workers' income" (p. 14), a long-term view with which E. G. Nourse cautiously took issue (1920). Ten months later, Warren concluded that there would be a general deflation affecting agriculture, but that it would be "more gradual" than after the Civil War. J. R. Fain, the president of the association, posed the question of whether farm prices falling below cost of production during a period of adjustment could be "restricted to a short period or avoided altogether" (p. 8).

With these moderate views prevalent, a heated debate over the causes and the appropriate responses by farmers and government followed the collapse of prices in 1920. Farm groups focused their ire on the Federal Reserve System (Shideler). It was held responsible for fueling speculation during 1919 and for the general deflation collapse of farm prices during 1920–21. It was also accused specifically of restricting credit to agriculture, a claim that proved false but which contributed to a crisis atmosphere as prices fell (Link).

The argument that the 1920–21 deflation caused relative prices to shift against agriculture was pursued in studies by Warren (1920, 1928). His conclusions, which became a basis for policy efforts to raise the general price level in the 1930s, are illustrated in figure 2. G. W. Dowrie, of the University of Minnesota, also evaluated the effects of monetary deflation on agriculture. Dowrie agreed with Warren that FED policy intensifed the farm collapse but rejected Warren's main conclusion, finding instead that the factors primarily responsible for the postwar price deflation were overstimulated agricultural production resulting from high prices during the war, good crop conditions in 1920, and the collapse of "abnormal and unsound" sources of demand. Dowrie took issue with Henry A. Wallace (editor of *Wallace's Farmer* and soon to be the secretary of agriculture) and others who urged "farm activity to support a law instructing the Federal Reserve Board to take such steps as necessary to reach and maintain a price level 70% above pre-war" (Dowrie, p. 75).



INDEX NUMBERS OF PRICES OF FOOD AND THE COST OF LIVING, 1914 - 1927

The amount by which retail food prices are below the cost of living may be taken as a measure of the overproduction of food. The amount by which farm prices are below their usual ratio to retail prices is a measure of price disparity brought about by the failure of distributing charges to decline when prices fall. The present low farm prices of food are due to the latter cause rather than to overproduction.

Figure 2. Warren's analysis of prices

The effects of international capital movements on the demand for U.S. agricultural products also played an important role in the debate over postwar agricultural policy. The emergence of the United States as a net creditor during World War I was widely perceived to be of importance because agriculture had provided exports to service U.S. foreign debts throughout the nineteenth century (Holmes). Wallace put the argument succinctly: "The hard fact is that many of the nations of Europe are now in debt, and in the long run, debtor nations find it impossible to import goods as freely as creditor nations can" (pp. 81–82). Max Sering, of the University of Berlin's Agrarian and Land Settlement Research Institute, concluded more generally that it was difficult to see how a contraction of U.S. cultivated area and an extensive migration of farmers could be avoided if Europe was "not permitted a return to normal conditions" (p. 240).

However, the prospects for restoration of normal conditions in Europe were complicated in the aftermath of the war by demands for German reparations and repayment of U.S. war loans. Despite extensive negotiations to reduce these obligations, in his 1928 lecture Cassel viewed the remaining intergovernmental war debts as "the greatest problem the world has been confronted with in regard to international movements of capital" (p. 63). To the extent that reparations and debt repayments were feasible, they rested on the reemergence of competitive private international capital markets. American loans

to Germany during the 1920s financed reparation payments that in turn serviced war debts of the Allies. The private loans cycled back through reparation and debt payments did not provide large markets for U.S. exports, but the capital outflow was sufficient to finance a small U.S. trade surplus. Cassel concluded that this cycle could not go on indefinitely, and he expressed fear that the world would be faced with the real problem of reparation payments when private lending to Germany ceased.

Cassel recognized that in the absence of new loans, European repayment of war debts necessitated a U.S. trade deficit. But American interests, including many farm groups, were myopic on trade issues and resisted importation of European goods. Emergency legislation restoring tariffs to their high prewar levels was enacted in June 1921. Permanent legislation, increasing tariffs from an average of 27% to around 40%, was enacted fifteen months later (the Fordney-McCumber Tariff).

The postwar tariff legislation raised domestic nonfarm prices and, arguably, choked off agricultural exports. These effects became essential factors shaping agricultural policy. B. H. Hibbard, of Wisconsin, characterized agriculture's dilemma as being that "another world war would put food at a premium, a government subsidy might bring relief, a revision of the tariff downward would do likewise. Two of these remedies would be worse than the disease, the third measure would be a miracle" (p. 202).

In the absence of tariff reductions, the view which prevailed was to seek relief in specific measures of support for agriculture. Farmers were seen as the least organized group in an economy becoming affected more and more by collective action. Wallace argued that "farmers have just as much right to organize to control their output as union labor has to organize for the purpose of shortening hours and increasing wages" (1923, p. 16). This view gained support as demand adequate to raise prices for existing supplies failed to materialize (Holmes, Nourse 1927).

To obtain higher prices and incomes, farmers sought improved credit agencies, lower costs for farm-to-market transportation, strengthened cooperative marketing, and extension of the War Finance Corporation to provide export credits and credit assistance to farmers. Farmers also engaged in a contentious and prolonged battle for an export subsidy plan similar to the current policies of the European Community. The basic idea of the plan was to maintain prices at "parity" levels equal to those of the prewar period for output absorbed in the domestic market. Production in excess of domestic absorption would be sold at whatever prices the world market would bear, and individual farmers would receive an average price based on total national sales. The debate over farm policy centered on this proposal and alternatives to it. Legislation based on the plan was brought before Congress five times between 1924 and 1928 (Benedict). If failed to obtain majorities in the first three attempts. Subsequently, closely related legislation passed in both the House and Senate. Although they were vetoed on each occasion, these bills were the forerunners of the agricultural legislation enacted in 1933.

Implications

There are some important similarities between the 1910–29 period and the period since 1970. Initial prosperity in agriculture during inflationary years is followed in both periods by falling relative prices, collapse of export markets, increased international competition, asset-deflation and financial crisis, and failure of the sector to recover from a recession as quickly or as well as the overall economy. In the 1920s, the severity of the recession in agriculture was shared by sectors such as cotton manufacturing, coal mining, shipbuilding, and the shoe and leather industries. In the 1980s, some manufacturing sectors, such as apparel and primary metal products, have also remained relatively depressed and have faced intense international competition.

In this context, it is interesting to speculate about currency values and trade in the 1920s under alternative policies. The small U.S. accumulation of official reserves that occurred suggests that the dollar was slightly undervalued. Appreciation of the dollar would have brought the current and capital accounts into balance, given the debt repayment requirements and evident private investment decisions. Had the war debts been forgiven, then, all else being equal, the dollar would have been overvalued. To restore balance would have required depreciation of the dollar and an expansion of exports. Conversely, had international capital markets not functioned, repayment of the war debts would have resulted in a greater accumulation of official reserves or required a much stronger dollar, depressing exports further. Thus, war-debt policy served to increase the value of the dollar compared to what it otherwise would have been. The available private capital outflows facilitated

implementation of the fiscal policy by easing its effects on the exchange rate and trade sectors.

One can draw a comparison between the capital inflow required by the war debt repayments in the 1920s and the capital inflow induced partly by federal budget deficits in the 1980s. Fiscal policy has had a depressing effect on exports in both periods. The fiscal policies have also been feasible in both periods largely because of private international capital mobility.

A second comparison can be made between the inflation and capital movements during and after World War I, and the oil crises in the 1970s and extensive loans to the governments of hard-pressed developing countries. The strain on European recovery associated with war reparations and debts underscores the importance of resolving the current LDC's debt, and the tenacity of the U.S. position in the earlier debt-reduction negotiations, with eventual repudiation of their war debts by the Europeans, is sobering.

One dissimilarity between international capital markets in the two periods arises from the United States being a net source of credit in one period and a net borrower in the other. In the 1920s, capital movements enhanced the U.S. ability to export compared to the situation if new capital flows had not occurred, while the rising net asset position of the United States augered for eventual deterioration of exports relative to imports. In the 1980s, exactly the opposite is the case. Contemporaneous capital movements are a cause of poor U.S. export performance, while the deteriorating net asset position augers for eventual improvement of exports relative to imports.

Moreover, the magnitude of the recent capital inflows to the United States is unprecedented in this century, and the U.S. level of net foreign debt is on the verge of surpassing its level in 1900. This raises the question of whether we, like Cassell and Wallace, should be concerned that a country cannot borrow indefinitely, as we now know was infeasible for Europe in the 1930s. More specifically, it raises the question of whether the high level of U.S. debt foreshadows expanded agricultural exports to service the debt load, in a manner analogous to the pre-World War I period?

It appears that interest payments resulting from the current trade deficits will not necessarily lead to trade surpluses by themselves, at least not over the next decade. The current balance of net investment income barely favors foreigners despite the U.S. foreign indebtedness (see fig. 1). Net capital inflows of 2% of GNP—high by historical standards but less than recent net capital movements—imply that annual trade deficits will stay on the order of \$100–\$150 billion until the year 2000. But annual net interest payments due to foreign investors may rise to only 0.5% of GNP. This situation need not force a swing to a trade surplus.

Of greater issue is that new capital inflows of even 2% of GNP for another decade would continue to be unprecedented. Net U.S. debt to foreign investors would rise to 20% of GNP. Such an increase might heighten public sentiment about foreign takeover of the economy and could threaten free capital markets.

This is where the real concern arises. The relevant question is whether net capital inflows can be reined in while avoiding the sharp recession and drop in trade that accompanied both the end of Treasury financing after World War I and the shift in private capital flows in the early 1930s. Unification of the European market and revitalization of the centrally planned economies could stimulate world income growth and are important to the United States in this context. So, too, is easing of the debt burden of the developing economies and progress in the GATT negotiations. On the other hand, even modest capital market restrictions, say a foreign investment tax, might pose more of a threat to continued prosperity than the burden of servicing growing net interest obligations. Ironically, restrictions on capital movements also would pose a threat to U.S. agricultural exports by endangering world income growth.

A final remark concerns the interface of agricultural policy with monetary policy, international capital flows, and trade policy. In his seminal paper on exchange rates and agriculture, Schuh demonstrated the effects of the overvalued dollar on the development of agricultural policy during the 1950s and 1960s. Similarly, a lesson one can draw from the interwar period is that relatively free capital markets, which Cassel called "the only illuminating point" in a dark picture of economic relations among countries after World War I, cannot compensate for other distortions. The agricultural policies that originated in the 1920s, and were adopted in the 1930s, were consequences, perhaps inevitable, of the monetary policies, tariff policies, and war reparation and debt policies that were implemented. We can only speculate how agricultural policy would have evolved under the liberal trade regime and more adequate restoration of the European economy that were advocated as an alternative in the 1920s. But we

are right to be asking in forums such as GATT whether reform of agricultural policies is overdue in light of other policy changes that have occurred in the United States, Europe, and elsewhere.

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International Financial Markets and Agricultural Adjustment in North America: Discussion

Terry L. Roe

I begin with a discussion of the Carter, Gray, and Furtan paper and then turn to Orden's paper. I conclude with only a few remarks on Villa-Issa's paper.

First, I take exception to the conceptual framework in CGF, not because the framework is incorrect, nor does it necessarily alter the conclusions drawn from their empirical results. Instead, the approach (their fig. 1) ignores the importance of capital markets in exchange rate determination, while the others, figures 2 and 3, illustrate the problem of casting questions of exchange rates into a partial equilibrium framework. The Slater model is a model of the current account. Their point C, figure 1, is characterized by a small country where expenditure equals income and the excess demand is zero at relative prices RR'. A disequilibrium is generated when, for example, a monetary authority increases the money supply causing actual cash balances to exceed desired balances. Then, an excess demand is generated for home and traded goods as expenditures exceed income. To satisfy excess demand, the authority must sell foreign exchange for domestic currency at some given rate of exchange or draw upon reserves. The new and temporary equilibrium lies to the right and above C denoting higher relative price for home goods and increased consumption of both home and traded goods. The deficit in the trade balance is something less than the increase in the money supply because some portion of it will be absorbed by voluntary increases in money holdings. In a two-country model, a devaluation causes consumers to reduce real expenditures in the devaluing country and to increase spending in the other country. Changes in the terms of trade depend on differences in the country's marginal propensity to consume traded goods. Changes in reserves are not dealt with directly and these flows have no direct impact on income.

As Krueger and Chipman (1989) point out, current account models are necessarily disequilibrium theory and questions of the consequences of altering the exchange rate cannot be answered without considering how it is altered; some other variable, notably capital market variables, must change to alter portfolio balances and influence trade flows, which together determine currency values. The causation is often from changes in capital market variables to a change in the exchange rate. Stylistically, a reduction in the home country's budget deficit will tend to decrease its excess of expenditures over income and hence increase the supply of exports and reduce the demand for imports, which in turn may alter the country's terms of trade. But this change alone may not be sufficient to induce the foreign country to reduce its export surplus, i.e., its excess of income over expenditure. The reduction in the devaluing country's budget deficit will lower its demand for loanable funds from the foreign country. The decreased demand for loanable funds in the home country will tend to release the funds in the foreign country for use in its consumption expenditures. It is through this capital market transaction that the foreign country is induced to reduce its export surplus.

Models of the interaction between the current and capital accounts tend to treat exchange rate equilibrium as a balance compatible with home country time preferences relative to investment opportunities at the world interest rate. The fractions of wealth held in various assets are functions of nominal and real interest rates and expected rates of currency depreciation. These variables link country's asset markets. For instance, individuals in a devaluing country may change their portfolio balance by selling assets abroad, lowering their prices and increasing interest rates, thus calling forth the requisite cash

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from abroad. At any point in time, the asset market determines the exchange rate, which impacts on wealth through current account imbalances; this wealth, current account, capital account mechanism determines the path of the long-run exchange rate (Krueger, p. 105).

The next point to emphasize relates to the misleading insights that can come about from misinterpreting the partial equilibrium diagrams, figures 2 and 3 in CGF. To illustrate, suppose the diagrams depict economies composed only of traded goods. Then, in terms of these diagrams, changes in the nominal exchange rate will appear to yield the indicated effects. However, this is an illusion. The general equilibrium restricted profit function is homogenous of degree one in prices. Hence, changes in the nominal exchange rate equal the product of the nominal exchange rate and variable profits evaluated at world market prices; supply and factor demand are homogenous of degree zero in prices so no change in production or factor use levels occur. Moreover, the indirect general equilibrium utility function is homogenous of degree zero in prices, so changes in the nominal exchange rate yield no change in utility. If there are home net puts, or fixed factors of production, then changes in utility will depend on whether the prices of home net puts, and the shadow prices of the fixed factors, are functions of the prices of traded goods. There are special circumstances where changes in the prices of trade goods will have no impact on net put prices (Chipman 1974), although this is unlikely the case of fixed factors. But then, the wealth implications of changes in the shadow prices of fixed factors are also not accounted for in figures 2 and 3.

The empirical content of the CGF paper is interesting, and the conclusions seem appropriate to the extent that inferences based on either the Slater or the partial equilibrium diagrams are conditioned by the weaknesses of these constructs. I do feel that exchange rates are not exogenous to changes in prices, particularly when both countries are large so that changes imply income effects. In any case, the exogeneity of exchange rates is an empirical question; the conceptual one is clear: for the domain of price changes observed in their data, and ignoring other contemporaneous correlations, a violation of the exogeneity assumption may not alter the key insights obtained to the empirical questions posed.

The version of the Orden paper I received required several readings. The paper has many insights that are not easily organized. Orden first discusses international capital movements for the period 1900 to 1989. He then focuses on the cycles in agricultural prices and incomes for the period 1914 to 1921. The review version of the paper also contained a table of current and capital account data for the entire period, which helped to enrich this discussion. With the aid of the table, merchandise trade and investment income balances and corresponding capital account balances help to depict the adjustments that occurred over the period. It is clear, for example, that capital market flows were large relative to the trade imbalances in the 1920s and again in the 1980s, and that foreign capital flows relative to GNP are becoming more important in the 1980s. Had Orden provided a historical perspective on the nominal and real exchange rate adjustments over the period, it is likely that a stronger association could have been made between the increased demand for the U.S. dollar following World War I (because of European debt) and the depressed conditions in agriculture during the 1920s.

The third section of the paper focuses on the 1919–29 period. There are a number of interesting insights form this discussion. First, the recognition that intergovernmental debt affected the capacity of European countries to import U.S. commodities. Another insight is the political economy induced by changes in the 1920s. Special interest groups in agriculture were motivated to seek protection from declining export demand and increased import substitution in foreign countries. Still another: had capital markets not functioned in the 1920s so that no reverse capital flows from the United States to Europe occurred, then, to maintain the observed import levels, Europe would have had to increase its exports of goods and services (including agricultural products) to the United States, thereby making conditions in U.S. agriculture even worse then those realized. Put another way, the U.S. dollar would have had to appreciate even farther to restrict U.S. exports and to induce European imports in order for Europe to meet debt payments.

In the fourth section, analogies are made between the experience of the 1920s and the 1980s. The analogies between European debt in the 1920s and the U.S. fiscal deficit and developing country debt suggest further insights into the role of capital markets and trade in goods and services. The analogies also suggest a number of "what if" questions. Perhaps more attention might have been given to key differences between the two periods. These include the extent to which

world trade is now dollar based relative to the 1920s and the large proportion of international capital flows that in the 1980s were controlled by the private sector relative to the public sector. Another is the demand for U.S. dollars that is stimulated by both the U.S. fiscal deficit and LDC debt, which is also largely denominated in dollars.

I leave the review of Villa-Issa's paper to the other discussant, except to point out that the Mexican experience is not different from a number of the other countries included in the World Bank's study of the political economy of agricultural price policy in eighteen countries (Krueger, Schiff and Valdes). Essentially, import substitution and cheap urban-based food policies led to direct taxes on agricultural exports for many countries. In response to declining foreign exchange earnings, some countries subsidized the production of import-competing crops. In many cases, the indirect effects of industrial protection and an overvalued currency served to increase the taxes on agriculture by magnitudes exceeding direct taxes. Reform in many countries was forestalled when rising world prices for either petroleum or some other exportable permitted countries to maintain these implicit tax regimes. If reform occurred, it often came as increased farmgate prices or subsidizing inputs while maintaining low retail-level prices for staples. These policies made many countries vulnerable to the world market shocks of the early 1980s. The constituencies of these policies became entrenched, so that when adjustment was needed, negotiations between the various interest groups and the realignment of coalitions either did not occur fast enough or waited until a country faced a liquidity crisis. Then, the choice was to retreat to barter trade or undergo stabilization and structural readjustment policies supported by the World Bank and the International Monetary Fund. In either case, the old policies had to be discarded. What is particularly interesting is the extent to which the adverse adjustment costs faced by Mexico might have been decreased if increases in private capital flows lessened the need to shrink absorption and expand exports to meet the minimal demands of debt repayment. Hence, we once again turn to questions of how international capital markets influence trade flows.

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Performance of Mexican Agriculture: Discussion

Odin K. Knudsen

The importance of macroeconomic events and policy in influencing the incentives to agriculture has become one of the stylized facts of modern agricultural economics. Schuh's papers, beginning in 1974 on the relation between exchange rates and agriculture, are one of the major contributions in establishing this fact for North American agriculture. The recent World Bank studies guided by Krueger, Schiff, and Valdes provide additional evidence for developing countries by showing that indirect taxation of agriculture through maroeconomic policy has overwhelmed the positive protection given import-substituting agriculture through direct interventions on pricing and trade.

The papers presented in this session reaffirm this growing evidence of the importance of macroeconomic phenomena in determining the incentives to agriculture. In particular, Villa-Issa's paper outlines how changes in government policy in Mexico affected agriculture in particular from the postwar period. He implicitly hypothesizes that these linkages occurred through import-substituting protection and macroeconomic policy as reflected by changes in the real exchange rate and the internal terms of trade between agriculture and industry. In this note, I will elaborate on this linkage in the case of Mexico from 1965 to the present.

The Agricultural Real Exchange Rate

Although the real exchange rate is supposed to influence agricultural incentives through changing relative prices of tradable to nontradables, in the case of Mexico this transmission was imperfect because of government interventions. Although most agricultural products produced in Mexico are tradable, quantitative restrictions (including prohibitions) on exports and imports and price guarantees and controls tended to insulate agriculture from international prices and softened price transmissions to the domestic economy. Therefore, the real exchange rate alone is an imperfect indicator of overall agricultural incentives versus nontraded goods. What is needed is a more specific indicator that links agricultural prices of tradable commodities to the prices of nontraded goods (one could consider the real exchange rate as a weighted average of these sector-specific real exchange rates). To do this, we define the agricultural real exchange rate E_a as the price of agricultural tradables P_a to the price of general nontradables P_n,

$$(1) \qquad E_a = P_a/P_n = (P_a/P_t)E_r,$$

where P_t is the price of tradables and E_r is the real exchange rate.

Therefore, the agricultural exchange rate depends on the price ratio of agricultural tradables to general tradables times the real exchange rate for the economy as a whole. Defining TT as the external terms of trade of agriculture versus tradable commodities, t_a as the rate of protection of agriculture, and t_t as the protection offered tradables in general, we get from (1),

$$(2) \qquad E_a = TT(1 + t_a)/(1 + t_t)E_r.$$

Thus, the agricultural exchange rate is a function of the external terms of trade of agriculture, the differential protection offered agriculture versus other tradables, and the real exchange rate. This agricultural exchange rate enables us to find how the incentives to Mexico's agriculture were changing.

In figure 1, we plot this sector-specific exchange rate along with the economy-wide exchange rate and the rate of agricultural GDP growth. It is immediately evident that agricultural growth has been considerably more volatile than real exchange rate movements in the 1960s and 1970s and that there is no apparent correlation between the two.

The agricultural real exchange rate moved more or less in parallel with the economy-wide real exchange rate until the 1980s, when they di-

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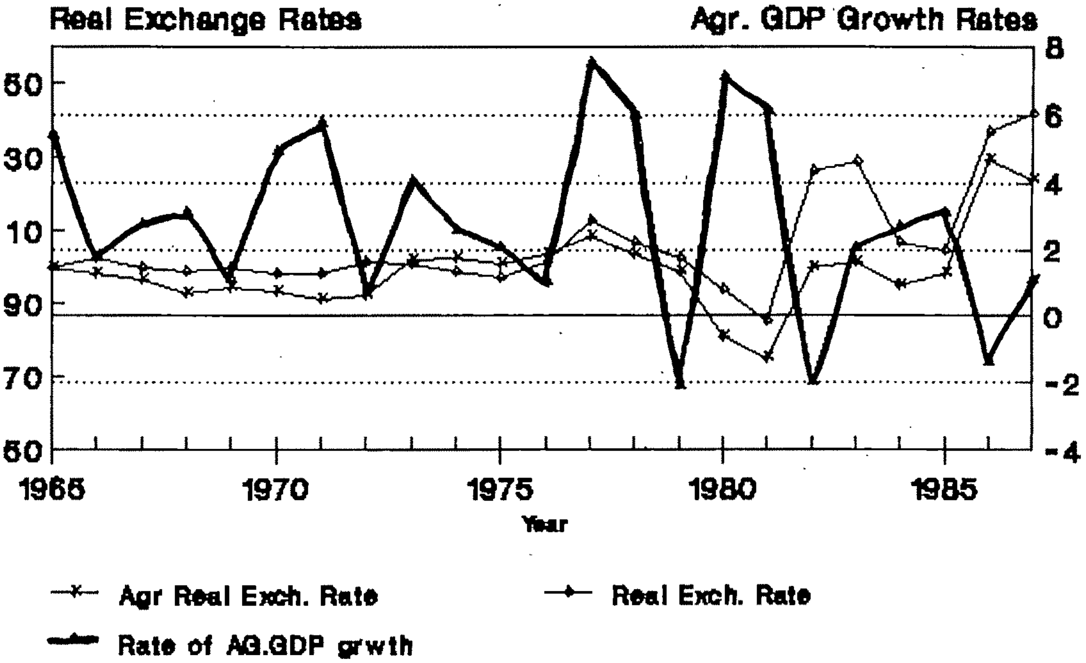
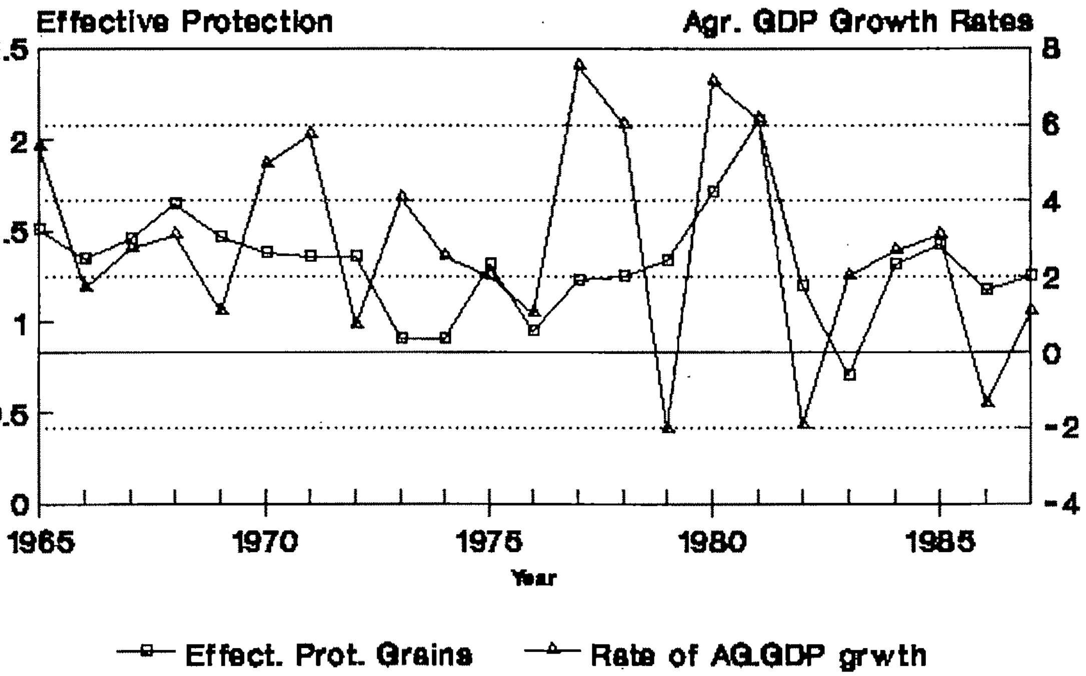


Source: World Bank data.

Figure 1. Real exchange rates and growth



Source: World Bank data.

Figure 2. Effective protection and growth

verged by nearly 30%. The economy-wide real exchange rate remained remarkably stable until the nominal devaluation in 1976, while the agricultural exchange rate slowly appreciated until the commodity boom of the mid-1970s. After 1976, both real exchange rates appreciated until 1981, with the agricultural exchange rate appreciating even more than its economy-wide counterpart. With the onset of the debt crisis in 1982, both exchange rates rapidly depreciated; but, with import licensing reaching 100% of trade in 1983, the depreciation of the agricultural exchange rate was less severe. Following this widening between the exchange rates in 1981 and 1982 and the collapse of many agricultural interventions, especially after 1985, the agricultural exchange rate reconverged to the economic-wide exchange rate, with both depreciating by about a third. Nevertheless, agricultural growth faltered.

If, as in figure 2, we examine real protection for grains, defined as the weighted nominal protection corrected for the real exchange rate, the volatility of incentives is evident. Plotted against the agricultural growth rates, it appears that part of the instability in agriculture results from this volatility in the incentives, caused in part by direct interventions and macroinfluences.

In conclusion, it is clear that agriculture in Mexico has experienced particularly unstable incentives in the late 1970s and 1980s. Except in the early 1980s, these incentives *vis-à-vis* nontradables have followed the macroinfluences reflected by the real exchange rate, despite heavy direct intervention in agricultural trade and markets.

Federal Support to Farm Lending (Marc Johnson, Kansas State University, presiding)

Imperfect Information and the Theory of Government Intervention in Farm Credit Markets

Robert D. Innes

This paper describes some possible economic motivations for government intervention in farm credit markets. These motivations are made possible by explicit departures from the perfect information and complete market assumptions that underlie both the neoclassical competitive paradigm and the fundamental theorems of welfare economics. To be more precise, the analysis focuses on three types of asymmetric information between farmers and prospective outside investors, both of whom are assumed to be risk neutral. Arguably, the three informational asymmetries examined here represent natural departures from "perfect markets" in that, unlike the unencumbered neoclassical model, each elicits farmers' optimal use of debt contracts (rather than equity instruments or other contractual forms) to raise investment capital. Despite their consistency with observed contractual choices, all three of the models analyzed below yield free-market equilibria that diverge from first best/perfect information outcomes. Given the inefficiency of these market equilibria, the key question raised and discussed here is: Can government improve upon the derived competitive outcomes and, if so, how?

Despite the enormity of the credit rationing literature, only a few extant studies address this question in models that are consistent with debt contracts. Among them are DeMeza and Webb (1987, 1988, 1989) and Innes (1988), which focus on the third type of informational asymmetry considered below. The other two information structures posited in this paper have been studied in several analyses of credit markets, but with attention focused on positive attributes of the unfettered competitive equilibrium rather than on prospective implications for welfare-enhancing government intervention. In what follows, this literature is surveyed and, for the first two information structures, some new policy results are presented. A critical discussion of the paper's limitations concludes the article.

The One-Period Model

Consider a population of risk-neutral farmers, each of whom can invest in his farm today and realize a net worth (also called profit) tomorrow of $\pi = \pi(A, \varepsilon; x)$, where A denotes the total farm investment today, $\varepsilon \in [0, \bar{\varepsilon}]$ is a random variable with continuous density (distribution) $h(\varepsilon)(H(\varepsilon))$, and x is a nonstochastic variable to be defined later. The total farm investment, A, is financed by external (nonfarmer) funds of I, and a given amount, $A - I$, of the farmer's own wealth. In all of the model variants analyzed below, it can be shown that a farmer will invest all of his own financial resources in the farm. Therefore, $A - I$ can be treated as fixed. Moreover, when relevant (and without loss in generality), the population of farmers will be defined to have a common level of initial wealth/collateral, $I - A = W_0$. The external investment, I, will then determine A, and we can define the probability density and distribution functions for π by $f(\pi; I, x)$ and $F(\pi; I, x)$, respectively; $f(\ )$ is assumed to be strictly positive on $[0, K(I, x)]$ and zero elsewhere.

External investors are assumed to be risk neutral, rational, and competitive in the sense that they are willing to sign financial contracts which yield them an expected return of ρ, the return on a risk-free bond. The farmer/investor financial contract specifies both the external investment level, I, and the farmer's payment to the external investors for each possible realization of π, $B(\pi)$. Because of the farmers' limited li-

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ability, $B(\pi)$ cannot exceed π, a constraint which rules out a fixed payment contract.

In a first-best world without any information problems, an optimal $B(\pi)$ can take any form that satisfies limited liability and that yields the investors their required expected return, ρ. Further, a first-best setting will yield an investment level, I, which solves the following maximization:

$$(1) \qquad \max_{I} E(\pi; I, x^*) - (1 + \rho)I,$$

where E is the expectation operator for π, x^* will be defined appropriately in what follows, and $E(\pi; I, x)$ is concave in (I, x). The solution to (1) will be denoted by I^*, which is assumed to be positive.

We now turn to an analysis of three different imperfect information structures. For each of these structures, relevant properties of the equilibrium farmer/investor financial contracts will be presented and the welfare effects of prospective government credit market interventions will be described. In evaluating welfare effects of policy interventions, two different criteria will be applied:

Criterion 1. Can the sum of all agents' expected payoffs be increased by the intervention?

Criterion 2. Can the intervention, together with an appropriate compensation scheme, elicit a Pareto improvement?

Because compensation has allocative effects in the models analyzed here, the answers to these questions often diverge.

Model 1: *Ex-Post* Asymmetric Information

Following the development in Gale and Hellwig (also see Townsend, Diamond, and Williamson), suppose that external investors cannot observe *ex-post* farm profit, π, or the state of nature, ε, unless they incur an observation cost of $c(I, \varepsilon)$, where $\forall(I, \varepsilon) \gg 0$, $c > 0$, $c_I \geq 0$, $c_\varepsilon \geq 0$, and $c_{II} \geq 0$. *Ex-post* profits here are simply $\pi(A, \varepsilon)$ (without x), with $\pi(\ )$ assumed to have the following properties: $\pi_A > 0$, $\pi_\varepsilon > 0$, $\pi_{AA} < 0$, and $\pi_{A\varepsilon} > 0$.

After profits are realized (i.e., after the value of ε is determined), the farmer will report a profit (or ε) level to the external investors. In principle, the farmer's report may or may not be honest. However, from the revelation principle, a contract which sometimes elicits dishonest reports is equivalent to another which always elicits honest reports (e.g., see Harris and Townsend). Restricting attention to the latter incentive compatible contracts, the farmer/investor financial agreement will specify the set of profit (or ε) reports for which investor observation occurs. If N represents the set of ε realizations wherein investors do not observe π, then $\forall\varepsilon \in N$, the farmer can and will pay investors the minimum level of $B(\pi)$ consistent with $\varepsilon \in N$, namely, $B_N \equiv \min_{\varepsilon \in N} B(\pi(A, \varepsilon))$. Thus, for incentive compatibility, $B(\pi(A, \varepsilon)) = B_N \, \forall\varepsilon \in N$. In addition, if $B(\pi(A, \varepsilon))$ were greater than B_N for some $\varepsilon_0 \notin N$, then the farmer would never report ε_0; therefore, for incentive compatibility, $B(\pi(A, \varepsilon)) \leq B_N \, \forall\varepsilon \notin N$. Given the farmer's limited liability, these incentive compatibility requirements imply that the investors must observe profits in some states of nature in order to ever obtain a positive payoff. For a given I, an optimal financial contract will minimize the expected costs of investor observation subject to the incentive compatibility, limited liability, and investor return requirement constraints. A debt contract achieves this minimum by setting $N = \{\varepsilon : \varepsilon \geq \varepsilon^*, \text{some } \varepsilon^* > 0\}$ and $B(\pi(A, \varepsilon)) = \pi(A, \varepsilon) \, \forall\varepsilon < \varepsilon^*$, thereby maximizing the payments in observation states and minimizing the probability of observation. Thus, we have:

PROPOSITION 1. *In model 1, equilibrium contracts take a standard debt form.*

Proof: See Gale and Hellwig, Proposition 4.

Note that, with debt contracts, investor observation implies farmer bankruptcy so that $c(\ )$ can now be interpreted as a bankruptcy cost.

Given proposition 1, the farmer's investment choice problem is as follows:

$$(2) \qquad \max_{I, \varepsilon^*} \int_{\varepsilon^*}^{\bar{\varepsilon}} (\pi(W_0 + I, \varepsilon) - \pi(W_0 + I, \varepsilon^*))h(\varepsilon)d\varepsilon,$$

$$(3) \qquad \text{s.t. } G(I, \varepsilon^*) \equiv \int_0^{\varepsilon^*} (\pi(W_0 + I, \varepsilon) - c(I, \varepsilon))h(\varepsilon)d\varepsilon + \pi(W_0 + I, \varepsilon^*)(1 - H(\varepsilon^*)) - (1 + \rho)I \geq 0.$$

Substituting from (3), problem (2) can be rewritten as

$$(2') \qquad \max_{I, \varepsilon^*} J(I, \varepsilon^*) \equiv \{E(\pi; I) - (1 + \rho)I\} - \int_0^{\varepsilon^*} c(I, \varepsilon)h(\varepsilon)d\varepsilon,$$

subject to (3). The solution to problem (2′) will be denoted by $(\hat{I}, \hat{\varepsilon}^*)$.

Because problem (2′) is constructed as a constrained optimization of one agent's utility subject to another agent's achievement of a given expected payoff, its solution is constrained Pareto optimal (i.e., a criterion 2 welfare improvement is not possible). However, so long as the farm does not always go bankrupt (i.e., $\hat{\varepsilon}^* < \bar{\varepsilon}$), this solution is not first best, setting $\hat{I}$ less than I^*. The reason is that, at the optimum, a marginal increase in I requires an increase in ε^* (i.e., an increase in the probability of bankruptcy) in order to preserve the investors' expected return. (If a marginal increase in I above $\hat{I}$ did not require ε^* to rise, this increase in I would unambiguously raise the value of the farmer's objective function in (2) and $\hat{I}$ could not be optimal.) Therefore, with the *ex-post* informational asymmetry posited here, marginal investment has an additional cost (*vis-à-vis* the first-best case) of raising expected investor observation costs, $\int_0^{\varepsilon^*} c(I, \varepsilon)h(\varepsilon)d\varepsilon$.

The deviation of $\hat{I}$ from I^* admits the possibility that government policy can increase total net expected payoffs in the credit market. For example, if the government simply gave the farmer I^* dollars today, the farmer would choose the first-best investment level, finance it entirely with his own funds, and thereby save the economy the investor observation/bankruptcy costs.[1] However, lump sum transfers to farmers may be very costly to achieve for a variety of reasons, including the incentives that they create for nonfarmers to invest resources in seeking the transfer rents. Therefore, it is of interest to examine the scope for another policy instrument, interest subsidies, to yield gains in total expected payoffs.

Letting ρ_0 denote the unsubsidized cost of funds, we now consider a marginal subsidy on ρ, $s > 0$, which implies a subsidized cost of funds equal to $\rho_0 - s$. Since $J(I, \varepsilon^*; \rho_0)$ represents the total (economy-wide) net expected payoff from farm investment, this marginal subsidy will be welfare improving (in the sense of criterion 1 above) if $J(\hat{I}(\rho_0 - s), \hat{\varepsilon}^*(\rho - s); \rho_0)$ is larger than $J(\hat{I}(\rho_0), \hat{\varepsilon}^*(\rho_0); \rho_0)$, where the dependence of J, $\hat{I}$, and $\hat{\varepsilon}^*$ on ρ is now made explicit. The following propositions can now be derived (see Innes 1989b for proofs):

[1] Leathers and Chavas make a similar point. However, in their model rational farmers and investors would not choose the contract forms that are assumed to prevail.

PROPOSITION 2. *Define $I^\dagger(\varepsilon^*; \rho) \equiv \text{argmax}\ J(I, \varepsilon^*; \rho)$. Then $\hat{I}(\rho_0) < I^\dagger(\hat{\varepsilon}^*(\rho_0); \rho_0) \leq I^*$ if $\hat{\varepsilon}^*(\rho_0) < \bar{\varepsilon}$.*

PROPOSITION 3. *Suppose that $\hat{\varepsilon}^*(\rho_0 - s) \leq \hat{\varepsilon}^*(\rho_0) < \bar{\varepsilon}$ so that a marginal subsidy does not lead to an increase in the probability of farm bankruptcy and, in the absence of subsidies, the farm does not always go bankrupt. Then some subsidy on ρ, $s > 0$, will yield a criterion 1 welfare improvement (i.e., it will increase the total economy-wide net expected payoff from farm investment).*

PROPOSITION 4. *Suppose $\hat{\varepsilon}^*(\rho_0) < \bar{\varepsilon}$, and let $I_G(\varepsilon^*, \rho)$ solve $G(I, \varepsilon^*; \rho) = 0$. Then a credit subsidy policy, $s > 0$, which limits subsidies to investment levels less than or equal to $\bar{I} \equiv \min(I^\dagger(\hat{\varepsilon}^*(\rho_0); \rho_0), I_G(\hat{\varepsilon}^*(\rho_0); \rho_0 - s))$ will yield a criterion 1 welfare improvement.*

A subsidy on ρ will affect the levels of both investment and ε^* (i.e., the probability of bankruptcy). By reducing the investor's required return, the subsidy has the direct effect of reducing ε^*. However, the subsidy is also likely to elicit an increase in I, which raises ε^*. If the first direct effect dominates the second investment effect (as assumed in proposition 3), then the subsidy has two beneficial consequences: (*a*) it leads to a level of I, which is closer to that which maximizes economy-wide net expected payoffs, $I^\dagger(\ )$, and (*b*) it reduces the probability of bankruptcy, thereby saving the economy some bankruptcy costs. However, even if the investment effect dominates the direct effect, benefits from a subsidy policy can be insured by limiting the subsidy to investment levels that do not increase the probability of bankruptcy. Proposition 4 defines such a policy.

Model 2: Moral Hazard

Now suppose that there are no informational asymmetries about profit realizations (as in model 1) or farmer attributes (as in model 3), but that the farmer makes an effort choice that affects the farm profit distribution and is unobservable to external investors. Because the effort level, e, is hidden, the farmer/investor financial contract cannot specify e and, in setting financial contract parameters, investors must infer effort choices from the farmer's underlying choice problem. Thus, a standard principal agent problem emerges.

To analyze this problem formally, let $x = e$

and assume the following ($\forall \pi \in [0, K(\ \ )]$ and $\forall(I, x) \in R_+^2$):

$$(4)\quad \frac{\partial}{\partial \pi}\left(\frac{f_x(\pi; I, x)}{f(\pi; I, x)}\right) > 0, F_I(\ \ ) < 0,$$

and $B(\pi)$ is nondecreasing

Equation (4) implies that higher levels of x (i.e., e) and I elicit better profit distributions in the sense of the monotone likelihood ratio property, MLRP (see Milgrom), and first-order stochastic dominance, FOSD, respectively. (Note that the MLRP implies FOSD, but not vice versa.) Assuming $B(\ \ )$ to be monotone provides a weak restriction on contract forms that can be motivated by a prospective ability of investors to sabotage the farm *ex-post.*

For expositional convenience, the following implication of (4) is now stated, deferring its explanation until later:

PROPOSITION 5. *In model 2, equilibrium contracts take a standard debt form, $B(\pi) = min(\pi, z)$.*

Proof: See Innes (1990).

Proposition 5 implies that the financial contract is fully characterized by the pair (I, z). Given (I, z), the farmer is considered to choose effort to solve the following problem:

$$(5)\quad \max_e \int_z^{K(I,e)} (\pi - z)f(\pi; I, e)d\pi - v(e),$$

where $v(e)$ is the disutility of effort, with $v_e > 0$ and $v_{ee} > 0$. Denoting the solution to (5) by $e(I, z)$ (a function which the investors are assumed to know), the following investor return requirement implicitly defines $z(I)$, the promised payment demanded by investors when they invest I dollars in the farm:

$$(6)\quad E(\min(\pi, z)|I, e(I, z)) = (1 + \rho)I.$$

Abusing notation somewhat, a given investment level I elicits the effort choice $e(I) \equiv e(I, z(I))$. With a substitution from (6), the complete choice problem can now be stated as follows:

$$(7)\quad \max_{I,e} E(\pi|I, e) - (1 + \rho)I - v(e) \quad \text{s.t} \quad e = e(I).$$

The solutions to (7) will be denoted by $(\hat{I}, \hat{e})$. As in model 1, these equilibrium outcomes are the solutions to a constrained optimization problem and, hence, are constrained Pareto optimal (Brander and Spencer). However, they are not first best.

In order to relate $(\hat{I}, \hat{e})$ to their first-best counterparts, it is useful to define a quasi-first-best effort choice function, $e^*(I)$, as the solution to the following problem:

$$(8)\quad \max_e E(\pi|I, e) - (1 + \rho)I - v(e).$$

The following relationship can now be derived (see Innes 1989b for proof):

PROPOSITION 6. *$e(I) < e^*(I)$ when $I > 0$.*

For a given investment level, the farmer employs less effort than he would in a first-best world for the following reason. Being unable to commit to a given e, the farmer must share some of the benefits from marginal effort (i.e., the resulting increase in expected profits) with the external investor, while bearing the full disutility cost of marginal effort, $v_e(e)$. Of course, the farmer would like to commit to an effort level that is as close to $e^*(I)$ as possible. This desire motivates debt contracting. To be specific, marginal effort shifts probability weight from low profit levels to high profit levels. By choosing a contract form that maximizes his own payoffs in high profit states, the farmer will maximize his incentives to exert effort and thereby permit himself to implicitly commit to a higher level of e. Among all possible monotonic contract forms, debt contracts maximize the farmer's payoff in high-profit states of nature, thereby minimizing the disparity between $e(I)$ and $e^*(I)$.

The deviation from a first best suggests scope for policy interventions to yield criterion 1 welfare benefits. To explore this possibility, note that, because of proposition 6, the constraint in problem (7) can be replaced by the inequality restriction, $e \leq e(I)$, without loss in generality. This restatement of problem (7) is convenient because it implies the following proposition:

PROPOSITION 7. *The following conditions are sufficient for a policy measure to elicit a criterion 1 welfare improvement in model 2: The policy (a) raises $e(I)$ for all $I > 0$, and (b) preserves the farmer's objective function in (7).*

Proof: From (*a*), the policy enlarges the opportunity set for the modified problem (7) [i.e., (7) s.t. $e \leq e(I)$]. Therefore, from condition (*b*), proposition 6, and by revealed preference, the policy elicits a higher value of the objective function in (7). Q.E.D.

Now consider the following two policies: (*a*) A government grant to the farmer of G, where G is (*i*) given at the time that profits are realized and (*ii*) not large enough to fully cover the farm-

er's loan obligations at the post-grant equilibrium. (*b*) An interest subsidy, $s > 0$, on investment levels no greater than $\bar{I}$, where $\bar{I}$ is less than the (post-subsidy) equilibrium level of I. When $s\bar{I} = G$, these two policies are equivalent, each yielding the following augmented investor return requirement:

$$(6') \quad E(\min(\pi, z)|I, e(I, z)) = (1 + \rho)I - G,$$

(6′) implicitly defines $z(I, G)$, with $z_G(\ ) < 0$. Substituting from (6′), the farmer's choice problem is identical to problem (7) except that the constraint becomes $e \leq e(I, z(I, G)) \equiv e(I, G)$, where

$$(9) \quad e_G(I, G) = e_z(I, z(\ )) \cdot z_G(\ ) > 0.$$

Therefore, these policies satisfy the requirements of proposition 7 and elicit criterion 1 welfare gains.

Model 3: *Ex-Ante* Asymmetric Information

Finally, following Innes (1988), consider a setting in which there are no moral hazard problems or profit observation costs but there is asymmetric information about the quality, q, of a farmer's profit distribution. Each farmer is either high ($q = H$) or low ($q = L$) quality and is assumed to know his own quality type. However, external investors cannot directly observe a farmer's q and, in the absence of farmer signaling, can only infer that a given agricultural borrower is high quality with probability θ, where θ is the proportion of high quality borrowers in the population of farm loan applicants. Farmer signaling/self-selection can occur if two financial contracts emerge in equilibrium, one of which is preferred by high-quality farmers and the other of which is preferred by low-quality farmers.

In this model, the variable x corresponds to q, the farmer's quality type, and the conditions in (4) are assumed to hold. Thus, high-quality farmers have better profit distributions in the sense of the MLRP. It is also assumed that high-quality farmers have better marginal investment returns in a sense to be made precise momentarily.

Following Wilson, equilibrium in this model is a set of contracts $(B_q(\pi), I_q)$, $q = L, H$, which maximizes the net expected payoff of the high quality entrepreneur subject to three constraints:

(*E*1) investor return requirement: investors earn at least their required expected return, ρ, on each distinct contract;

(*E*2) incentive compatibility: low-quality farmers weakly prefer their own contract; and

(*E*3) low-quality payoff: low-quality farmers earn an expected payoff at least as high as on their perfect information contract.

(*E*1)–(*E*3) represent feasibility constraints on the equilibrium. Moreover, since investors are competitive, any contracts which satisfy (*E*1)–(*E*3) but do not solve the posited high-quality farmer maximization problem will be supplanted by investor offers of the contracts that do solve this problem; the latter solutions will attract the business of at least the high-quality farmers, thereby earning the investors that offer them no less than (and possibly greater than) their required expected return.[2]

For this specification, the following result is proven in Innes (1989a):

PROPOSITION 9. *In model 3, any equilibrium contract either takes a standard debt form or is equivalent to one which does.*

In essence, debt contracts maximize investor payoffs in low entrepreneurial profit states of nature. Since low-quality types have probability weight concentrated in these states, high-quality agents, by taking a debt contract, can minimize the low-quality types' incentive to masquerade. The incentive compatibility constraint (*E*2) is thereby relaxed, permitting higher net expected profits for the high-quality entrepreneur. Thus, proposition 9 emerges and, as before, a contract can be completely described by a pair, (I, z).

Two graphical constructs now permit a simple characterization of the equilibrium (see fig. 1): (1) Farmer indifference curves (IC_q), which give the (I, z) contracts that yield a quality q farmer a given (constant) net expected payoff,

$$IC_q: \int_z^{K(\ )} (\pi - z) f(\pi; I, q) d\pi = \text{constant}.$$

(2) Investor offer curves, which give the (I, z) contracts that yield investors exactly their required expected return when (*a*) the contracts are taken by a quality q farmer (OC_q) and (*b*) the contracts are taken by both types of farmer (OC_p, where p is for "pooling"),

$$OC_q: E(\min(\pi, z)|I, q) = (1 + \rho)I.$$

$$OC_p: \theta E(\min(\pi, z)|I, H) + (1 - \theta)E(\min(\pi, z)|I, L) = (1 + \rho)I.$$

[2] See DeMeza and Webb (1989) and Innes (1988) for a more complete motivation of the Wilson equilibrium.

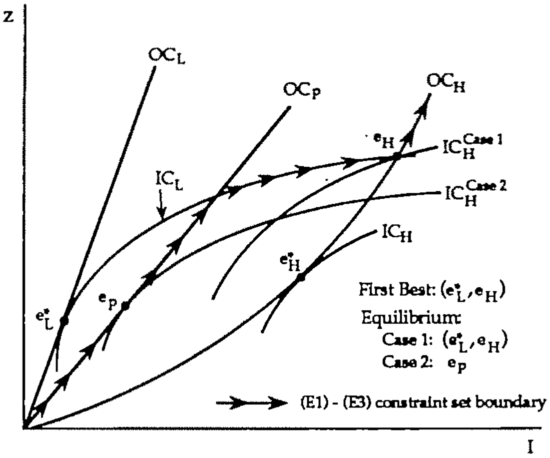

Figure 1. Model 3 equilibrium

Because farmers "like" investment, I, and "dislike" payments to investors, z, indifference curves are upward-sloping and lower curves (in fig. 1) correspond to higher farmer payoffs. In addition, it is assumed that high-quality indifference curves are steeper than low-quality indifference curves due to superior high-quality marginal investment returns.[3] Since investors like z and dislike I, offer curves are also upward-sloping. Further, OC_H is below OC_L due to "better" high-quality profit distributions.

The first-best in this model is the set of tangencies between IC_q and OC_q for $q = L, H$. To make the analysis interesting, it is assumed that these contracts violate incentive compatibility in that the low-quality farmer prefers the high-quality type's first-best contract to his own (see fig. 1). Two types of equilibria are then possible.

Case 1: As shown in figure 1, the equilibrium high-quality contract corresponds to the point on the $(E1)$–$(E3)$ constraint set (as indicated by arrows) that is on the lowest IC_H; in case 1, this contract is e_H, which exactly deters adverse selection by low-quality farmers.

Case 2: When the high-quality farmer prefers his favorite pooling contract, e_p, to e_H, e_p emerges in equilibrium.

The following proposition is now graphically evident (see Innes 1988 for a proof):

PROPOSITION 10. *(i) In a model 3 pooling equilibrium (case 2), $I_L < I_L^*$ and $I_H > I_H^*$, where I_q^* is the first-best investment level for a quality q farmer. (ii) In a model 3 separating equilibrium (case 1), $I_L = I_L^*$ and $I_H > I_H^*$ (i.e., the high-quality farmer overinvests in order to signal his type).*

Given the equilibrium's deviation from a first-best, it is of interest to evaluate the prospective welfare benefits of typical policy interventions. For space reasons, only one type of intervention is considered here, namely, the government's direct offer of a subsidized credit contract that is designed for low-quality farmers. In figure 2, a subsidized contract, e_L^s, is constructed so that low-quality farmers invest at their first-best level and are indifferent between e_L^s and the first-best high-quality contract, e_H^*. It is assumed that either (*a*) e_L^s is above OC_H so that high-quality farmers would not choose to take e_L^s and obtain supplemental private financing, or (*b*) the government offer of e_L^s is combined with a requirement that any takers of this contract obtain no supplemental financing. Then the government offer of e_L^s will elicit a first-best equilibrium by reducing the low-quality farmer's incentive to masquerade as high quality, thereby relaxing the incentive compatibility constraint which is driving the free-market inefficiency. A criterion 1 welfare benefit will thereby result from the intervention.[4,5]

A Few Extensions and Limitations

(*a*) *Entry by inefficient farmers*. DeMeza and Webb (1987) study an analog to model 3 with fixed investment levels (per farm) and the presence of many different farmer quality types. This model yields a pooling (all-debt) equilibrium wherein the lowest quality farmer that operates (i.e., borrows and invests) has a sufficiently poor profit distribution that he would not farm in a "first-best" setting. The reason for the presence of these inefficient farmers is that, in equilibrium, they face a high-quality-farmer-subsidized interest rate which is lower that they would face with perfect information. The resulting ov-

[3] Milde and Riley construct a model in which low-quality indifference curves are steeper due to identical high- and low-quality marginal investment returns. Implications of the latter specification are discussed in Innes (1988).

[4] Model 3 competitive equilibria can often be improved upon in the criterion 2 sense as well (see Innes 1988).

[5] A similar policy result can also be derived in fixed investment models wherein costly collateral provision serves as a signaling mechanism (e.g., see Besanko and Thakor, and Chan and Kanatas).

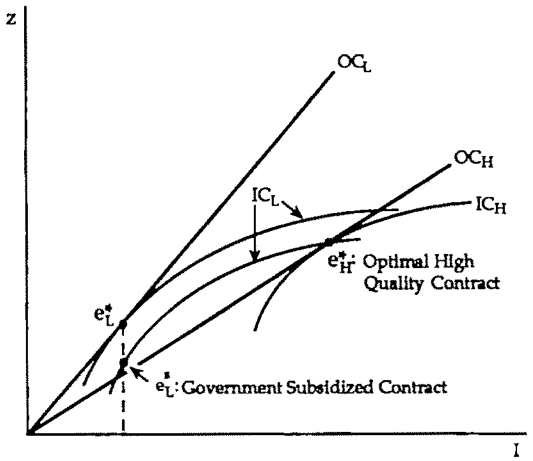

Figure 2. Proposed government debt subsidy policy

erinvestment can be deterred by taxing the loan contract rather than providing subsidies. If farmer investment choices are permitted, as in model 3 above, the possibility of entry by inefficient farmers (i.e., "lemons") may or may not alter the policy conclusions described here [see Innes (1988, pp. 28–29)]. However, the tradeoffs created by a joint policy objective of curtailing both signaling costs and inefficient production by "lemons" deserves more rigorous analysis.

(*b*) *Alternative market and information structures*. This paper has assumed that investors are competitive. However, in many cases, farmers may face a small number of possible lenders, yielding investor market power that can have important implications for the positive and normative properties of equilibrium.[6] In addition, banks (investors) may conceivably be in a position to obtain an informational advantage over farmers concerning both the farmer's own "quality" type and the attributes of his profit distribution. The latter possibility contrasts sharply with the construction of model 3 and merits further thought.

(*c*) *A final caveat*. For obvious reasons, the paper abstracts from several issues that are likely to be important in gaining a fuller understanding of farm credit markets. Foremost among these abstractions is the role of government as a frictionless and benevolent intervenor. In fact, government is subject to political economic forces as well as costly frictions in the processes of both raising revenue and allocating subsidies. Of equal importance are the neglect of equilibrium effects in output and input (e.g., land) markets, and of dynamics.

[6] See the interesting papers by Chambers and Lee, and Besanko and Thakor for some discussion of monopoly lender behavior in financial markets with asymmetric information.

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The Effects of Federal Credit Programs on Farm Output

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Institutions with the direct or implied support of the federal government have supplied on average in the 1980s 45% of total credit received by the agricultural sector of the U.S. economy. The Farm Credit System (FCS), a borrower-owned cooperative whose bonds carry an implied federal guarantee, held about 27% of total outstanding farm debt in 1987. The Farmers Home Administration (FmHA), a federal agency that makes loans to farmers who are attempting to cope with emergency situations, held an additional 17%.

A primary objective of these public credit programs is to facilitate agricultural production by providing credit that, presumably, would be unavailable to farmers from other sources (Meekhof; Barry and Boehlje, pp. 129–30).[1] This justification for federal support in the supply of credit to farmers raises at least two issues. First, because it seems unlikely that private sector lenders would forego profitable lending opportunities, both a rationale for this discrimination against farm borrowers and evidence that it exists are needed. Second, even if there were some discrimination against farmers as borrowers, the fungibility of credit suggests that at least some publicly supplied credit targeted for agriculture would be diverted to higher-yielding investments, thus reducing its effect on agricultural production. The issue in this case is not whether credit is diverted but, rather, the extent to which it occurs.

In this paper we use a model of credit rationing to evaluate whether farmers receive more of their credit from federal agencies when the aggregate supply of credit declines. We then examine the relationship between credit originating from the FCS and FmHA and changes in farm output.

Credit Rationing

Credit rationing typically is defined as an instance in which borrowers do not receive all of the credit they desire at the prevailing interest rate. Stiglitz and Weiss argue that banks may prefer to ration credit to borrowers on nonprice terms rather than raising interest rates in response to excess demand for bank credit because higher interest rates on loans may attract relatively high-risk borrowers or induce their existing loan customers to pursue riskier projects. To avoid this adverse selection problem, which may cause expected bank profits to decline, the credit-rationing hypothesis posits that banks attempt to make distinctions among borrowers on the basis of characteristics associated with relatively low risk. Thus, if farmers represent a relatively large share of those borrowers who are perceived as a high-risk group, they may receive less credit from the private sector when the aggregate supply of credit declines.

The credit-rationing hypothesis applied to agricultural credit markets implies several testable hypotheses. First, the share of government-supported lending to farmers should increase as a share of total lending to farmers when the aggregate supply of credit declines. This relationship is modeled formally in equation (1), where G is credit extended to farmers by the FCS and FmHA, TF is total farm credit, and TC is total aggregate credit.

$$(1)\quad \Delta \ln\left(\frac{G}{TF}\right) = a + \sum_{i=0}^{P} b_i\, \Delta\Delta \ln TC_{t-i} + e_t.$$

As written, (1) relates percentage changes in the share of total farm credit originating from the FCS or FmHA to changes in the growth rate of total credit. If farmers face credit rationing, the sum of coefficients on changes in the growth

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[1] More background on the justifications for farm credit programs is provided in Bosworth, Carron, and Rhyne, pp. 6–10 and chapter 5.

rate of total credit (*TC*) should be negative: the share of farm credit from government agencies will tend to rise when the growth rate of total credit declines.

An increase in the quantity of credit supplied to farmers by government-sponsored programs, however, may offset reductions (if any) in farm credit from the private sector. In this case, the total supply of credit to the farm sector would be insulated from the effects of changes in aggregate credit supply. To examine how changes in the aggregate supply of credit affect the share of total credit extended to farmers, equation (2) also was estimated:

$$(2)\quad \Delta \ln\left(\frac{TF}{TC}\right) = a + \sum_{i=0}^{p} b_i\, \Delta\Delta \ln AMB_{t-i} + u_t\,,$$

where the change in the growth rate of the supply of credit is measured using the adjusted monetary base (*AMB*). Growth of the *AMB* reflects Federal Reserve actions that affect the ability of banks to extend new credit. If credit rationing exists, the sum of coefficients for changes in the growth rate of the monetary base should be significantly greater than zero. That is, farmers would receive a smaller share of total credit when growth in the aggregate supply of credit slows. The relationships in equations (1) and (2) are similar to those reported by Blinder and Stiglitz.

The results of these estimations, using annual data over 1947–86, are reported in table 1. The models were estimated for lags on right-hand-side variables up to three years, but only the results for the best overall regressions are reported. The results from equation (1) offer some evidence that farmers face nonprice credit rationing. As growth in total credit slows, the share of farm credit from government sources is observed to rise significantly. Although equation (2) does not show a significant relationship between Federal Reserve actions that affect the total supply of credit and the share of total credit to farmers, these results nonetheless provide some evidence on credit rationing. A story consistent with these two results is that farmers are subject to credit rationing in the private sector [equation (1)] but, because of the federal credit programs, are able to maintain a fixed share of total credit during a contraction of credit supply [equation (2)]. Therefore, if the FCS and FmHA are justified on the assertion of a credit-rationing process, these results support that assertion.

Table 1. Results of Tests for Credit Rationing

$$(1)\quad \Delta\ln\left(\frac{G}{TF}\right) = \underset{(1.89)}{1.857} - \underset{(2.07)}{1.438}\Delta\Delta\ln TC_t$$

$\bar{R}^2 = 0.09$ $\quad F = 4.296 \quad$ D-W = 2.04

$$(2)\quad \Delta\ln\left(\frac{TF}{TC}\right) = \underset{(1.10)}{-1.330} - \underset{(0.16)}{0.155}\Delta\Delta\ln AMB_t$$

$\bar{R}^2 = -0.03$ $\quad F = 0.024 \quad$ D-W = 0.47

Note: Absolute values of *t*-statistics are in parentheses.

Credit in a Model of Agricultural Output

Even in the presence of credit rationing, an additional issue is relevant to the existence of federal agencies that direct credit to farmers. In this case the question is whether credit from public institutions will stimulate agricultural production. Because the FCS and FmHA typically lend to farmers at interest rates below those charged by private sector institutions, the public credit programs would tend to function more as a pure subsidy.[2] Variations in the subsidies, therefore, would induce variations in the amount of credit demanded from the public agencies. But borrowers, subject to the restrictions and monitoring of the public credit programs, could very well use the credit for purposes other than agricultural production. Moreover, restrictions on the nonagricultural use of farm credit from public agencies can be circumvented in a variety of ways.[3] Thus, if credit is diverted to its highest-valued opportunities and these are not in farm production, the existence of the federal credit agencies may have little impact on farm output.

Specification of the Model

The role of credit as a determinant of agricultural output can be analyzed within a theoretical model of the demand for and supply of agri-

[2] Bosworth, Carron, and Rhyne estimate the FCS is able to lend at rates 0.1 to 0.5 percentage points less than comparable private sector lenders. See their chapter 5 for more discussion of this subsidy and its effects.

[3] Suppose, for example, that a farmer receives subsidized credit from a public agency for the first time in the current year. If the farmer uses the funds from the public agency to buy his usual amount of farm inputs, his equity, which in prior years had been used to buy farm inputs, could be invested in nonagricultural concerns.

cultural output. Credit is incorporated into the supply function under the assumption that farmers must borrow in order to increase the quantity of inputs they employ.

Demand for agricultural output is specified as a function of contemporaneous real gross national product (GNP) and the difference between the rates of change in agricultural prices and prices of nonfarm commodities:

$$(3) \quad \Delta\ln Q_t^D = a_0 + a_1\,\Delta\ln RGNP_t + a_2\,(\Delta\ln P_t^F - \Delta\ln P_t^{NF}) + e_t\,,$$

where Q^D is demand for agricultural output, *RGNP* is real GNP, P^F is the price level for farm output, P^{NF} is the price level for nonfarm output, and e_i is a random error term $\sim N(0,\sigma^2)$. We expect $a_1 > 0$ and $a_2 < 0$. In general, this assumes that demand for farm output will move with changes in aggregate demand and will vary inversely with changes in the farm/nonfarm relative price ratio.

The supply function, equation (4), can be written as

$$(4) \quad \Delta\ln Q_t^S = b_0 + b_1\,\Delta\ln INPUT_{t-1} + b_2\,\Delta\ln PROD_t + b_3\,(\Delta\ln P_t^F - \Delta\ln P_t^{NF}) + \mu_t\,,$$

where Q^S is supply of agricultural output, *INPUT* is the real value of farm inputs, *PROD* is the productivity of farm inputs, and μ_t is an error term with classical properties. We expect b_1, b_2, and $b_3 > 0$. This specification incorporates a lag in production by making output in the current calendar year a function of the real value of inputs purchased in the prior year. The index of input productivity is derived by dividing an index of farm output by an index of mechanical power and machinery inputs.[4] Constructed in this way, the productivity measure reflects both transitory influences, such as weather, and more permanent influences, such as new types of machinery.[5] The relative price variable captures the responsiveness of the supply of agricultural production to changes in the relative price of agricultural commodities in the current year, given the investment of inputs made in the prior year.

Credit is incorporated into the supply function through a third equation that specifies agricultural inputs as a function of the real value of agricultural credit. That is, by writing

$$(5) \quad \Delta\ln INPUT_t = c_0 + c_1\,\Delta\ln CREDIT_t + v_t\,,$$

where $c_1 > 0$, it is possible to substitute the terms on the right side of equation (5) for the variable $\Delta\ln INPUT_{t-1}$ in equation (4). The reduced-form equation for agricultural output then is derived by treating the supply and demand functions as a system of equations and solving for $\Delta\ln Q_t$:

$$(6) \quad \Delta\ln Q_t = d_0 + d_1\,\Delta\ln RGNP_t + d_2\,\Delta\ln PROD_t + d_3\Delta\ln CREDIT_{t-1} + z_t\,,$$

where d_1, d_2, and $d_3 > 0$. In this reduced form, the relative price variable ($\Delta\ln P_t^F - \Delta\ln P_t^{NF}$), which appears in both the supply and demand functions, is eliminated and the coefficients d_0 and d_1 through d_3 are combinations of the coefficients on the variables in equations (3) through (5).

To use equation (6) to test hypotheses about the effect of public sector credit on farm output, the aggregate credit variable must be disaggregated. A first refinement separates total credit into real estate and non-real estate debt. The presumption is that real estate debt (*REDEBT*) should have little impact on output because it would be used primarily to finance transfers of ownership of farmland already in production. Thus, if credit has any effect on output, it should be associated with non-real estate credit (*NREDEBT*) used to purchase the variable inputs of production. A second division of total credit segments non-real estate credit into that provided by private sector lenders (commercial banks) and public sector lenders [FmHA and the Production Credit Associations (PCAs) of the FCS]. If public sector lending to agriculture increases farm output, either the FmHA or PCA variables should have significant and positive coefficients.[6]

Estimation

Farm output, the dependent variable in regressions reported in table 2, is the real value of U.S. gross domestic product in the farm sector as reported in the GNP accounts. Annual data are used; the number of annual observations is

[4] The choice of which input to use as a benchmark for a productivity series is somewhat arbitrary. The machinery series was chosen under the assumption that it is the type of capital expenditure most likely to be related to an extension of credit. See Ball for an analysis of measures of productivity in U.S. agriculture.

[5] Although the *PROD* measure reflects both transitory and permanent influences on the productivity of farm inputs, distinguishing between them is not crucial to the hypothesis under investigation, and no attempt is made to separate these influences.

[6] The coefficients on credit from public sector sources need not be as large as those on private credit, however, because credit from the public institutions may finance the operations of the least efficient farmers. Barry and Boehlje, pp. 137–41.

Table 2. Response of Farm Output to Changes in Credit

Independent Variable	Regression Number (1) 1941–86	(2) 1936–86	(3) 1936–86
Intercept	0.398	0.290	0.426
	(0.47)	(0.33)	(0.45)
$\Delta \ln RGNP_t$	0.120	0.091	0.090
	(0.95)	(0.75)	(0.68)
$\Delta \ln PROD_t$	0.742	0.720	0.750
	(6.25)	(6.21)	(5.97)
$\Delta \ln REDEBT_{t-1}$	−0.240		
	(1.85)		
$\Delta \ln NREDEBT_{t-1}$	0.147		
	(1.39)		
$\Delta \ln FLB_{t-1}$		−0.025	−0.042
		(0.21)	(0.34)
$\Delta \ln NFLB_{t-1}$		−0.229	−0.150
		(1.39)	(0.74)
$\Delta \ln PCA_{t-1}$		0.037	−0.012
		(0.51)	(0.12)
			0.127
$\Delta \ln PCA_{t-1} \times D$			(0.70)
$\Delta \ln FmHA_{t-1}$		−0.001	−0.014
		(0.02)	(0.25)
$\Delta \ln FmHA_{t-1} \times D$			−0.018
			(0.11)
$\Delta \ln BANKS_{t-1}$		0.109	0.129
		(1.76)	(1.55)
$\Delta \ln BANKS_{t-1} \times D$			−0.044
			(0.34)
$\bar{R}^2$	0.49	0.56	0.56
D-W	1.55	1.46	1.47

Note: Absolute values of t-statistics are in parentheses.

constrained by the availability of data on total farm debt, divided into the real estate and non-real estate components, which are available only since 1940. These data are used in regression (1) of the table. Data for selected categories of lenders are available from 1934 and are the basis of regressions (2) and (3).

The results in regression (1) indicate that neither the non-real estate nor real estate measure has a significant effect on farm output; contemporaneous values for the credit variables also failed to produce significant coefficients for any measure of farm credit. Regression (2), which distinguishes between credit originating from public and private sector lenders finds that none of the coefficients associated with non-real estate credit, either from the FmHA and PCAs or from commercial banks (*BANK*), is statistically significant at the 5% level. These results reject a link between public sector lending for the purchase of variable inputs and increased farm output. Of the real estate credit measures, neither that from the Federal Land Banks nor that from other sources has a significant influence on farm output. These results similarly refute the notion that farm output would be adversely affected by a deficiency in privately supplied credit for farmland purchases and question one of the primary rationales for the existence of the Federal Land Banks.

It should be recalled, however, that the observations on farm output and farm credit for about the first ten years of data used in equation (6) reflect unusual circumstances. The years include part of the Great Depression, when the banking system was weakened by widespread failures, and World War II, which had substantial effects on resource allocation. Assuming that the weakness of the banking system and poor returns in agriculture discouraged farm lending during this period, credit from government agencies may have been more important in facilitating agricultural production than during later periods. To account for the possibly unique influences for the years 1936–45, regression (3) adds variables that are the components of non-real estate debt in regression (2) multiplied by a dummy variable (D); this dummy takes a value of unity in the first years through 1945 and zero for subsequent years. Including the additional variables has little effect on the results: none of the credit variables is significant and the prewar–postwar distinction apparently is unimportant.

Conclusions

Federal involvement in the supply of farm credit is justified by arguing that there are imperfections in the supply of credit to farmers by the private sector. Tests for credit rationing provide evidence consistent with the idea of discrimination against farmers as a class of borrowers: when growth in total credit slows, the share of farm credit originating from federal agencies rises. Regression results for the influence of farm credit on farm output, however, reject the hypothesis that non-real estate credit either from public or private sources has positive and statistically significant effects on farm output. Thus, the results fail to indicate an important role for subsidized credit in facilitating agricultural production and, in doing so, suggest that this credit is fungible and diverted to higher-valued opportunities.

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Moral Hazard in Federal Farm Lending

Eddy L. LaDue

In financial markets, moral hazard occurs at both the institutional and borrower level.[1] It is currently an issue relative to commercial banks and, particularly, savings and loans, where the insurance provided by FDIC and FSLIC has resulted in high-risk activities by institutions under financial stress (Barth, Bartholomew, and Labich). Moral hazard at the individual level results whenever the borrower's economic environment contains incentives which encourage actions that reduce the probability of repaying a loan.

In its role as the lender of last resort to agriculture and as a social program to encourage entry or continuation in agriculture, the Farmers Home Administration (FmHA) operates a number of loan programs that the private sector would not provide. One of the problems that these programs face is that they provide economic incentives for the farmer to make decisions which reduce the likelihood of repayment and increase government costs. In the discussion that follows, I will (*a*) identify some of the more important situations where moral hazard may be important, (*b*) review the data available that indicate the presence or severity of the problem, and (*c*) discuss some of the possible procedures for minimizing costs.

Moral Hazard Situations

At a very basic level, the mere existence of a safety net program such as that provided by FmHA programs, particularly emergency loan programs, provides incentives for farmers and lenders to take higher-risk positions (Barry, Kaufman). Some farmers may undertake higher-risk activities, using private funds, knowing that if the venture is not successful, they will become "eligible" for FmHA programs. Lenders may encourage this strategy knowing that they have a good chance of shifting the borrower to FmHA should a financially distressed situation result (Herr and LaDue).

At the individual program level, FmHA's periodic reassessment provisions for their limited resource and low-income housing programs create strong incentives. Under these programs, borrowers are charged below market (subsidized) interest rates, and at periodic intervals, usually every two years, FmHA reviews the financial position and cash flows of the borrower to determine whether the borrower can afford to pay a higher interest rate. If cash flows will support greater interest payments than are currently being made, the interest rate being charged is raised to the lower of (*a*) the level the cash flow can support or (*b*) the unsubsidized regular (contract) rate in effect at the time the loan was made.

Within this environment, except for the lumpiness caused by the length of the reassessment interval, any increase in income is paid to FmHA in the form of higher interest payments until the rate of payments equals the contact interest rate. The borrower has little incentive to increase income unless the increase would push cash flow above the level necessary to allow payment of interest at the contract rate. In effect, the borrower receives zero marginal product for efforts required to get cash flows up to the contract rate and 100% of efforts above that level. Given the lumpiness of real-world activities, many activities with substantial marginal products that might push income over the contract rate level will not be undertaken because the marginal products received by the borrowers will be small. Farmers, and rural homeowners whose income comes from operation of small businesses, are encouraged to

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[1] Moral hazard is defined as actions of economic agents who maximize their own utility to the detriment of others in situations where the agents do not bear the full consequence (costs) of their actions because of uncertainty or the inability of the contracts used to assign full damages to the agent responsible (Eatwell, Milgate, and Newman). Moral hazard differs from adverse selection in that moral hazard refers to actions taken by managers which influence the performance, including risk, of the business, while adverse selection refers to situations where managers of higher risk or lower performing businesses are more likely to select (participate in) a program.

make investments in the business that will reduce current income (i.e., land and building improvements) but result in higher incomes in later years when subsidies are no longer being received. The program also provides incentives to underreport income whenever income is not clearly documented.

FmHA requires farmers to "graduate" to commercial credit whenever their income and financial position have sufficiently improved to obtain credit from other lenders. The contract rates charged by FmHA are generally the rate paid by the U.S. Treasury for funds of similar term plus up to 1%. Although such rates do not involve a subsidy payment by the government, they are normally considerably below competitive market rates for financing farm businesses. Some FmHA rates are fixed at even lower rates. Graduation, then, means giving up a favorable interest rate. Farmers nearing a financial position which would allow (require) graduation have little incentive to maximize income or reduce expenses, including family living expenses, when all, or a major part, of the income improvement would be paid to the commercial lender to cover the higher interest payment.

The loan guarantee program provides moral hazard incentives to the commercial lender. Because only 10% of any loss (90% guarantee) is borne by the lender, the economically rational level of attention to detail in loan documentation, servicing, and mitigation of losses on problem loans is much below the level that could be expected on the lender's nonguaranteed loans. Under these conditions, loan losses would be higher and lenders would have a tendency to follow the legal requirements "by the book" rather than the spirit within which they were developed.

The foreclosure moratorium which FmHA was effectively under for a number of years, as a result of *Coleman* v. *Block*, provided strong disincentives to repay FmHA loans. It was clear to farmers that no severe penalty could be assessed by FmHA for delinquency. The cost to the borrower for not paying local merchants and other lenders could be loss of services and of the ability to farm. The cost of not paying FmHA was minimal because they could not foreclose and do not compound late interest charges (do not charge interest on interest). Farmers who could not make all debt payments received a clear signal as to who not to pay. Farmers with (perceived) investment opportunities with higher rates of return than the rates charged by FmHA (zero on unpaid interest) had incentive to allow FmHA delinquencies to occur or mount.

The loan-servicing program, developed as a result of the Farm Credit Act of 1987, allowed farmers with insufficient cash flow to repay debts to pay off their debt by paying the recovery value to FmHA. The FmHA recovery value was the market value minus all costs FmHA would incur in foreclosing and selling the assets. In many cases this was a very favorable price for the assets. In most cases farmers in this financial condition could not obtain the financial backing necessary to pay the FmHA recovery value. However, because most of these farmers were headed out of business anyway, there was incentive for them to find a purchaser of the assets, for a price between fair market value and recovery value, who would provide the funds for the farmer to purchase the assets back at the recovery value. The assets would then be immediately sold to the funds provider (frequently in the parking lot outside the FmHA office) at a price favorable to both.

The most important set of moral hazard incentives created by FmHA programs likely results from their role as a last resort lender. Within that role, low-equity loans are extended. The borrowers frequently have promise but are not proven managers (Farm Ownership and Farm Operating Loans). They may also have been placed in a weak financial position by natural or economic disasters (Disaster Emergency and Economic Emergency Loan Programs).

Under this set of conditions, a significant proportion of borrowers will find themselves in a zero or negative equity position where the value of the business is less than the outstanding principal and interest on the loan (L). The value of the business that is relevant here is the recoverable value to the farmer (R). Although most farm assets are saleable, there are normally selling costs and, in some cases, contingent tax liability that will reduce the recoverable value. For many businesses, these costs may range from 10% to 25% of the market value of the assets.

Whenever $L \geq R$, the economic loss associated with failure is zero. The disutility associated with higher risk levels becomes small. High-risk strategies with a higher expected payoff and higher probability of failure become optimal. Given that an average farm business cannot generate the cash flow to make the payments on a very low-equity business (LaDue 1979), operators may, in fact, be economically forced to adopt such strategies.

The actual actions of a farmer will be modified to some degree by his or her expectations

relative to the probability that the business will be able to achieve a position where $R > L$. At the time most initial FmHA Operating and Ownership Loans are made, the expected probability is high. This is also true for some Emergency Loans. However, many Emergency Loans are made in situations where this is the last hope for survival, and the expected probability of survival is quite low.

Borrowers who have farmed with FmHA loans for a number of years and who still find that $R \leq L$ may be subject to a different set of expectations. As the expected probability of success declines, the perceived benefit from making payments to FmHA and maintaining assets used as collateral moves toward zero. Any income earned and not consumed becomes the property of FmHA with no benefit to the operator. This could lead to a lower level of input by the operator, nonmaintenance or nonreplacement of assets and increased consumption expenditures, particularly of luxury items.

The Emergency Loan programs are particularly susceptible to providing the financing that moves farmers into the position where the recovery value is less than the loan value and establishing cash flow requirements that do not allow recovery from that position. A farmer who obtains a loan for crop losses is effectively being allowed to spread much of one year's expenses over a number of years for a modest additional annual cost. This means that returns must be above average in the coming few years in order to pay for the annual installment on the crop loss. Unless the farm has above-average profitability, it is unlikely that income will be sufficiently high to allow the higher payment level and provide funds for any financial progress of the business. In these cases, the Emergency Loan programs tend to delay rather than forestall default and bankruptcy. Farmers tend to accept such situations because future bankruptcy is generally preferred to current bankruptcy.

Empirical Observations

The amount of data available to document the severity of the moral hazard problem for the Farmers Home Administration is small. For some cases, the observed results are the joint product of moral hazard and other factors, such as adverse selection and the normally lower success rate of highly leveraged farm businesses. This makes isolation of the moral hazard effects difficult. In other cases, FmHA does not collect and/or summarize the data that would be required.

The incentives generated by the interest subsidy reviews could be expected to result in most borrowers paying either the initial limited resource or subsidized housing rate (as long as potential income is less than that necessary to pay the contract rate) or the contract rate, with few paying any rate in between. Unfortunately, FmHA does not collect data at either the state or national level on the results of the subsidy reviews. The distribution of interest rates paid or the average rates paid by loan program could also provide evidence of the magnitude of this problem. However, the data are not summarized in this manner.

A national study of FmHA borrowers using data collected during 1977–78 (LaDue 1984) found that 17% of the existing Emergency Loan borrowers and 14% of the Farm Ownership Loan borrowers likely had the resources to graduate to other sources of credit but continued with FmHA in order to continue receiving low interest rates.

Unpublished data on a random sample of New York Emergency Loan borrowers interviewed in 1979 and 1986 found that of those still farming in 1986, 6% admitted that they could have obtained credit elsewhere. An additional 12% had over 70% equity in their business and three-fourths of these also had estimated net incomes above $25,000.

National FmHA data on the number of borrowers refinanced through other credit sources is also illustrative. The number refinanced during the year as a percentage of the number of borrowers at beginning of year declined precipitously in 1983, when the foreclosure moratorium eliminated FmHA's ability to force graduation.[2] The percentage of Operating Loan borrowers who refinanced declined from 2.6% in 1981 to 0.4% in 1983. Similarly, refinancing by Ownership Loan borrowers declined from 1.2% to 0.3%. Unfortunately, the deteriorating financial condition of agriculture contributed to this decline, making it difficult to determine the proportion of the decline that resulted from a voluntary reduction in graduation. Clearly, a significant number of farmers are finding ways to avoid graduation.

The USDA Office of the Inspector General (OIG) and the General Accounting Office (GAO)

[2] Number of borrowers refinancing from FmHA Report Code 813; number of borrowers from FmHA Report Code 616.

have reported the types of problems with FmHA guaranteed loans that moral hazard would be expected to generate. On the loan-making side, they found incomplete assessment of repayment ability, inadequate verification of income and debt, and imperfect documentation of collateral. Documented loan-servicing deficiencies include not obtaining periodic financial statements, not performing required collateral inspections, and making unauthorized loan advances under the guarantee. Although these studies did not compare their results to normal lender practice, the apparent degree of inadequate servicing appears significant. For example, of a sample of over 15,000 loans, OIG found that periodic financial statements were not obtained for 23% and collateral inspections were not conducted for 10%.

The loan-servicing program initiated in 1988 to handle delinquent loans marked the end of the foreclosure moratorium that had effectively been imposed for the preceding five years. Of the 66,426 borrowers who received foreclosure or servicing notices, many were already out of business or prepared for foreclosure (FmHA). However, more than 4,000 of the 35,146 who did respond, brought their loan to "current" status, or paid it in full at that time. These people clearly had the ability to keep current on their payments but had not done so. This underestimates the number of delinquent borrowers who had the resources to stay current because many county supervisors contacted borrowers who they thought could make their delinquent payments and indicated that receipt of these loan-servicing (foreclosure) notices could be avoided by bringing their accounts current. Original estimates of the number to receive notices ranged from 70,000 to 80,000. Many other farmers who did request one or more of the many options FmHA was offering undoubtedly allowed their delinquencies to FmHA to rise under the protection of the moratorium. These higher delinquencies are likely contributing to the high write-down and write-off costs currently being borne by FmHA.

Evidence on the degree of risk undertaken by low-equity borrowers compared to others is limited. Anecdotal evidence that low-equity borrowers have a higher tendency not to carry fire insurance on buildings (as well as other types of insurance) has been observed by many familiar with agricultural lending.

Expansion of a highly leveraged business involves higher risk than operation at the status quo. In the New York study of Emergency Loan borrowers, 15% of the borrowers with 25% or less equity expanded their businesses during 1979–86 through purchase of real estate. Sixteen percent of those with higher equity expanded. In the same study, 30% of the dairy farms with 25% or less equity expanded their businesses through purchases of animals. Only 16% of those with higher equity expanded similarly. This appears to provide some evidence of moral hazard. In some cases, however, increasing the livestock investment may sufficiently improve the input mix to result in lower business risk.

If low-equity farmers adopt higher risk strategies, higher variance in income levels could be expected. The standard deviation of 1986 net cash farm income in the New York study was $13,915 for low equity (≤25%) farms and $34,303 for higher equity farms. The coefficients of variation were 106% and 123%, respectively. Coefficients of variation estimated for a larger national sample of FmHA borrowers (LaDue 1984) were higher for Operating Loan, Farm Ownership, and Emergency Loan borrowers with less than $25,000 of equity than for higher equity borrowers.[3] Hence, the evidence is contradictory.

Farmers can use outside information sources to reduce the risk when considering expansion or large investments. In a 1987 survey, a random sample of all commercial farmers in New York State (LaDue and Kwiatkowski) were asked to identify the sources of assistance they used in making investment decisions. For expansion investments, cooperative extension or consultants were used by 20% of low-equity farmers and by 22% of other farmers.

FmHA personnel indicate that borrowers who perceive their probability of success as low do not maintain their collateral. Quality is allowed to deteriorate, and animals or machines are frequently not replaced. It is unclear whether this reflects explicit operator recognition that the returns to such maintenance are low or zero or an inability to purchase replacements because of cash flow limitations.

Minimizing the Costs

A particular problem that FmHA and other government lenders must bear is the low "moral cost"

[3] Midpoints of tabled values and number of borrowers for each range were used to estimate the coefficient of variation. Relationships were unchanged when more extreme values were used for the midpoint of the open ended high and low ranges of the tabled values.

(Jaffee and Russell) of default on government loans. Many borrowers convince themselves that defaulting on the government is not a serious transgression, rationalizing that the government got them into the problem, either through inappropriate price support policies or by lending the money (for examples, see GAO, Sep. 1989). Neighbors and friends frequently view not paying the government as less sinful than not paying local individuals or local businesses owned and operated by people they know. U.S. lenders rely on the moral cost of default to encourage effort to repay loans. This has historically been quite important for the farm population. However, the government gains less from this than do other lenders.

Government programs also operate under the handicap that they be "responsive" to the people. Thus, FmHA is less apt to take actions that are viewed as politically unpopular, and borrowers are provided many more avenues for leniency than a private lender could provide. For example, borrowers can use multiple levels of appeal, bring political pressure to bear, and make extensive use of legal recourse.

FmHA application forms and Farm and Home Plans typically list assets at their market value without adjustment for selling costs or contingent tax liabilities. To the degree that the borrower believes the net worth value calculated by such a procedure, he or she will tend to act as if the recovery value exceeds the principal plus interest, when in fact it is only the market value that exceeds the loan value. This equity illusion will increase the proportion of borrowers who believe the value of their business exceeds the value of their loans.

One of the commonly suggested methods of combating moral hazard in lending programs is to require collateral (Chan and Thakor). However, this usually involves additional collateral to that used in the business (i.e., a home or other nonfarm asset). Because FmHA is the lender of last resort, most borrowers do not have significant additional assets to pledge.

The method of minimizing moral hazard risk that likely has the greatest potential, particularly in a government setting, is use of complex financial contracts (Barnea, Haugen, and Senbet). This approach is already in use for some FmHA situations. To limit the "parking lot" sales of assets sold to the borrower at FmHA's recovery value, a recapture provision has been developed.

Similarly FmHA has written detailed procedures for correct making and servicing of guaranteed loans. The limitation of this approach, however, is that the procedure has become so complex that lenders may reduce their use of the program because of the complexity itself. This has led to further contracts in the form of preferred lender status for loan making where, once a lender's procedures are accepted by FmHA, loans put forth by that lender are guaranteed with modest further review.

Improved contracts in the form of completely documented annual financial statements, including a statement of cash flows and reconciliation of income statement and balance sheet, could be required. Such statements would allow more accurate business evaluations for adjusting subsidized interest rates and assessing graduation potential. This practice would be particularly useful where the problem is caused by inaccurate reporting. Given the positive relationship between maintenance of such records and success (LaDue and Christensen), such a requirement could have other benefits. FmHA's attempt to require coordinated financial statements was "shouted down" because of their complexity, but such statements may reflect the type of effort required to reduce moral hazard. Contracting can also be used for situations where a high-risk investment or income shifting to future years is clearly identifiable and appropriate penalties for conducting such activities can be identified. For example, maintenance of fire insurance could be monitored.

Conclusions

Moral hazard incentives exist for a number of FmHA's programs. Data are not available to allow a clear measurement of the risk involved for most programs. In cases where some documentation is available, the risk is apparent but relatively modest. Taken together, however, it is clear that moral hazard is a problem for FmHA. Improved contracts appear to be the most likely method of controlling the risk for continuing programs. Risks could be significantly reduced by not allowing foreclosure moratoriums, eliminating Emergency Loan programs or making such loans only when commercial lenders accept a substantial part of the risk, and returning to true supervised credit.

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Imperfect Information and Intervention in Farm Credit: Discussion

Daniel A. Sumner

In beginning a discussion of "imperfections" in farm capital markets, it is tempting to encourage the reader to study Stigler and just to stop there. However, given a couple of pages of *Journal* space, I cannot resist adding a few additional words that correspond more directly to Innes's paper.

Innes deals with three cases of costly and asymmetric information and for each finds that, in the simple and pure world in which his models reside, there is an opportunity to improve economic output by giving farmers money or credit subsidies. Let me stress two points at the outset. First, the basic results are not surprising: in the Innes world, we should expect "market" failure and "government" success. Second, Innes does not do the easy case in which the government is somehow immune from the costs of information that afflict the other agents in the model. In that sense, Innes is operating squarely within the realm of the famous Stigler observation that, "information costs are the costs of transportation from ignorance to omniscience, and seldom can a trader afford to take the entire trip" (p. 290). In Innes's models, not only is information costly, it is more costly for some than for others. The government differs from the other agents in these models, not in information costs but in that the objective of each other agent is to improve her own wealth, whereas the government acts to improve the total pie with no regard for who gets how much. Innes shows that in his "imperfect" world there are conceivable improvements to unfettered market forces. His final paragraph indicates, however, that even Innes may not take these results seriously as an indication that a real government could improve economic welfare but only as an indication that the market is not perfect.

A traditional debate among economists has been for a free market theorist to show that unfettered markets lead to some optimal allocations, and then for the response to be that in the real world the stringent conditions that lead to the optimality result do not hold. In part, the current exchange is just a reversal of the roles. The Innes paper shows theoretically that, in some rarified models, government subsidies lead to improved economic allocation. I argue that no one should expect these results to hold in practice, and that the practical problems in actual markets are overwhelming.

It is useful to list briefly the three cases that Innes studies and indicate the essence of his subsidy results. In model one, each farmer observes his own farm's output, but the banker does not without incurring significant costs. As a result, it is in the interest of the bankers to hold back on loans and to allow some excess farm failures. Innes shows that in such a world, an economy with more wealth in the hands of farmers or with subsidized credit on farm loans would produce more. If taxes did not distort and if the funds were distributed costlessly without themselves distorting behavior, then taking from taxpayers and giving to farmers would be profitable for the economy. The key here is that the asymmetric information costs and the chance that farmers will not reveal accurate data about their farm earnings cause bankers to loan less than might be socially optimal in a nicer world. The government, not worried about the cost to taxpayers or anything else, could improve economic efficiency.

The second case that Innes considers is the standard share contract problem applied to credit markets. About one hundred years ago, Alfred Marshall argued that because the share renter got only a portion of the returns for his effort, he would expend less effort than if he owned the land outright. Innes provides the same argument for farmers in the credit market. And the argument is clearly sound as far as it goes. The

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problem with the argument, as shown by the extensive literature of the last four decades, is that it does not go very far.

The incentive problem is solved in the credit market by the government giving farmers money, so that they have less interest in borrowing, or by subsidizing their borrowing itself. Forty years ago D. Gale Johnson emphasized, in the sharecropping case, that there are lots of ways to provide incentives. Contracts can be arranged to minimize incentives to shirk by including multiyear agreements and monitoring, among other things. In practice, the one clear applicable case of reduced incentives in farm credit concerns the lack of incentive of farmers to show enough progress to graduate from subsidized government loans of the Farmers Home Administration to private lenders.

The final case that Innes develops concerns good and bad farmers, each applying for credit. The farmers know which they are, but each farmer has an incentive to spend resources trying to convince the bankers that he is "good." Once again, waste and misallocation can be avoided if the government will distribute money to farmers. In this particular case, the information demands of the government in order to do the right thing are severe, but they do not include knowing a priori which farmers are of which type. The trick is that, if it knows enough technical information, the government can provide subsidies to bad farmers that cause them to reveal themselves.

It is also informative to note that the Innes models may prove too much. The same arguments that he applies to costly information about farmers by bankers applies to the costs of information about bankers by farmers and others. The result of applying the Innes model to banking would be that the government should subsidize banks, especially the incompetent ones.

As with any theoretical argument, the results of the Innes models would be different under alternative assumptions. For example, Innes assumes that farmers put all the eggs in their one "farming" basket. But, Belongia and Gilbert argue that one reason that farm output is unaffected by subsidized credit is that farmers divert part of their total resources to risk-reducing or returns-enhancing nonfarm investments. If this option were allowed in the Innes models, the major results might evaporate.

The bottom line is that it may be interesting to have had these models set out in the context of farm credit, but no one should think that they help justify the real government participation in real farm capital markets.

References

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Effect of Federal Credit Programs on Farm Output: Discussion

Howard D. Leathers

Five reasons have been advanced for government intervention in farm credit markets: (*a*) to mitigate effects of credit rationing, (*b*) to correct underinvestment in agriculture, (*c*) to subsidize some group, (*d*) to counteract effects of lender monopoly power, and (*e*) to reduce default costs. Belongia and Gilbert (BG) focus on the first of these and address two important questions: (*a*) Do commercial lenders ration credit to agriculture? (*b*) Would addition of government-supplied farm credit stimulate production?

It is difficult to define credit rationing in a real-world context. Credit rationing is distinct from underinvestment or discrimination. In making a loan, a lender first collects information about each potential borrower and divides the total pool of borrowers into groups (e.g., good and bad risk borrowers). All members of a group are indistinguishable to the lender but are not necessarily identical (information is imperfect). Second, the lender designs a contract to offer to each group. Credit rationing occurs when some member of a group cannot receive credit on the terms offered to the group (Stiglitz and Weiss). Underinvestment occurs when the terms offered result in a loan size which is less than the social optimum (Innes). Discrimination occurs when the contract offered to one group differs from the contract offered to another.

The existence of credit rationing means that some borrower could earn enough profits to repay the loan but cannot get the loan; thus, there is an obvious role for government. But is credit rationed to farmers? BG says yes because government share of farm credit increases as the growth rate of total credit declines. I am sympathetic to the answer but not entirely convinced by the reasoning. First, I know of no basis in theory for thinking that the incidence of credit rationing increases as the credit supply shrinks; if government perfectly corrects for credit rationing, its share of credit will not necessarily rise as credit declines. Second, theoretical models (in which borrowers have limited liability) predict that credit is rationed to the least risky borrowers (Stiglitz and Weiss). This is at odds with my intuition about what kind of borrowers patronize government lenders. Third, the relation estimated by BG relates government share of farm lending not to total credit but to change in total credit. The former would seem to be a more appropriate representation of BG's argument, as I understand it.

The BG evidence seems to imply that FCS and FmHA act to smooth out the supply of credit to agriculture. This may be attributable in part to the fact that FCS must estimate future demands for its credit before deciding how many bonds to sell. (One hears anecdotal evidence that in certain periods, FCS has excess funds and local PCAs and FLBAs try to "drum up business.") This mechanistic explanation seems consistent with BG's evidence [equations (1) and (2)] but imputes no policy objective to the FCS decisions. The desire of FmHA to provide credit to certain farmers who are unable to obtain credit from other sources would also explain why government share of farm credit increases when credit tightens. FmHA's goal here is redistribution (to help a certain groups of farmers) rather than efficiency (to counteract credit rationing). As LaDue discusses, failure on the part of FmHA to discriminate among groups of borrowers may exacerbate a moral hazard problem, leading to efficiency losses.

In their second section, BG examine whether farm credit programs have increased farm output or whether the credit provided by these programs has been diverted to nonfarm uses. They conclude that subsidized credit has not increased production, which seems to imply that government programs have been largely ineffective. I am uncomfortable with this conclusion for two reasons. First, if the FCS and FmHA programs are acting to smooth out the supply of farm credit, as suggested above, then total (production) credit should be positively related to output, but gov-

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ernment credit should not be related to output. Second, there may be some econometric explanations for the BG results. BG find that coefficient d_3 in equation (6) is not significantly positive. But $d_3 = [b_1c_1/b_3]/[1/b_3 - 1/a_2]$. For b_3 (supply elasticity) sufficiently high, d_3 will be close to zero even when b_1 and c_1 are positive. In addition, growth in productivity is probably not independent of past borrowing, so part of the effect of credit could be captured by the productivity variable.

While theoretical work has advanced in terms of explaining actions and interactions in credit markets, empirical work has lagged behind. The BG paper is a useful first step. Their paper raises important issues and suggests some interesting lines of research. If the government credit programs act to smooth out the supply of credit, is that an unintended consequence of the programs? Does it result from a desire to subsidize certain groups? Is it an effective way of counteracting the effects of credit rationing, or is there some other rationale? Are changes to these programs or new programs needed to deal with the effects of credit rationing?

Reference

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Moral Hazard in Federal Farm Lending: Discussion

Marc A. Johnson

LaDue presents (*a*) situations identifying moral hazard in FmHA programs, (*b*) empirical observations supporting the existence of moral hazard, and (*c*) suggestions for minimizing the cost of moral hazard.

A more precise definition of moral hazard is required than LaDue implies. Moral hazard is the hazard that an individual will succumb to the temptations (incentives) not to try to fulfill the objective an agency is helping him or her achieve. Thus, moral hazard is, in part, defined by the policy objective of the agency. LaDue assumes that the policy objective of FmHA is to serve as a lender of last resort and to encourage entry and continuation of families in farm enterprises. Stated differently, the farm credit policy objective is to save family farms or to extend the margin of opportunity to stay in farming below the line of performance acceptable to commercial credit markets.

FmHA borrowers are observed using cheaper credit to undertake riskier farming strategies in order to stay in farming. They are observed to pay local merchants first, to maintain a flow of inputs onto the farm, and repay FmHA last. They are observed to invest in nonfarm ventures with higher returns than farming to generate cash for the farm family. They are observed investing in land and animals to gain farm size efficiencies. However, these actions could be consistent with the policy objective of FmHA and do not necessarily represent moral hazard. Moreover, underreporting income is not moral hazard; it is fraud, similar to underreporting income on tax returns.

LaDue's remaining situations represent moral hazard. The agency's two-year loan reviews that search for the ability to pay higher interest rates may provide an incentive not to try to raise income because the marginal income goes back to the government. However, the individual farm family would have to exhibit a despairing lack of hope for success, not to try to break past the ability to pay commercial interest rates. Another moral hazard situation is where commercial lenders with only a 10% risk share put a low priority on loan service on FmHA guaranteed loans. When defined in a narrower sense, the cost of moral hazard to taxpayers is less than LaDue implies.

Empirical measurement of moral hazard suffers from a lack of precise modeling and a lack of data. None of LaDue's empirical observations can be explained only by moral hazard. The fact that a small percentage of farm firms could have obtained commercial credit, or could have graduated to commercial interest rates, or did bring their loans current after the moratorium could be explained by the borrower's quest for greater security and liquidity before deciding to stay in farming. Businesses on the edge of failure often will drop their insurance and adopt risky strategies in a last effort to survive, regardless of who supplies credit. Inadequate documentation and loan servicing on agricultural loans were widespread in the mid-1980s, not just for FmHA guaranteed loans. Empirical verification of moral hazard in federal farm lending will require sufficient modeling and data to pinpoint taxpayer losses resulting directly from intentional lack of effort by borrowers and participating bankers.

LaDue's recommendations to reduce loan losses resulting from moral hazard represent good business practice, i.e., require strict borrower record keeping with annual financial statements, more collateral, complex financial contracts, and strict lender servicing procedures. These remedies have been tried. FmHA was phasing in consolidated financial statements for borrowers in the early 1980s, but political action was used to stop the practice. A principal borrower complaint in the early 1980s was that FmHA required assignment of virtually all assets of the farm family to get an FmHA loan, leaving nothing to offer as security on additional commercial credit. Moreover, attempts by FmHA to achieve

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compliance on their loan contracts resulted in a five-year moratorium on foreclosure. Strict paperwork and lender servicing guidelines nearly scuttled the FmHA loan guarantee program; procedures were eased to attract bank interest in the program.

LaDue summarizes by saying, "It is clear that moral hazard is a problem for FmHA." However, based on the results of his paper, the conclusion is too strong.

A related question is whether the FmHA is a cost-effective way to save family farms. When policy makers observe that the credit market is less lenient with farmers than taxpayers would desire, it is questionable whether a government program can improve on conditions at a reasonable cost. Three considerations are important. First, is moral hazard likely at the agency, whereby efforts to maintain the agency's budget and clients would reduce the incentive to try to graduate all farm families? Second, can a program be designed to help farm families survive without trapping them in a cycle of low performance, with high implied tax rates on marginal income? Third, how can a program be cost effective under a cloud of policy uncertainty; for a while FmHA is a social agency dispersing cheap credit, and then it becomes a sharp penciled lending agency foreclosing on loans. When better management techniques are attempted, political forces intervene. When lender functions are attempted, a foreclosure moratorium is called. Are federal farm credit programs really the best way to save the family farm?

A Price Forecasting Competition (Arnold Zellner, University of Chicago, presiding)

A Price Forecasting Competition: Introduction

Christopher S. McIntosh and Jeffrey H. Dorfman

Accurate forecasts are important to professional agricultural economists. Forecasts are used not only for predicting random variables but as proxies for unobservable expectations in many analytical settings. When using forecasts, the analyst strives to obtain the most accurate forecast possible, where "accuracy" is determined by the specific objective of the forecasting exercise. Forecasts can be obtained by (*a*) purely judgmental approaches, (*b*) structural econometric models, (*c*) univariate time-series models, (*d*) multivariate time-series models, or (*e*) any combination of the above. The problem becomes one of choosing the most appropriate method (or combination of methods) for a given application.

Professional agricultural economists need to understand various forecasting approaches and how they differ from one another. Such information would aid forecast users in making rational choices regarding which forecasting methods to employ for a given application. A "best" forecasting method may not exist in all situations. Any one of the methods (or combination of the methods) mentioned above may provide the best forecasts in a given situation according to a particular loss function. Makridakas et al. summarize the conclusions from several previous studies by saying (*a*) judgmental approaches are not necessarily more accurate than objective methods, (*b*) causal (structural) econometric methods are not necessarily more accurate than time series methods, and (*c*) more complex or statistically sophisticated methods are not necessarily more accurate than simple methods.

The purpose of this paper is to present a forecasting competition, where three different techniques are applied to the identical information set of seven variables in an attempt to forecast two of the seven variables out of sample. All the forecasts will be judged by the same criteria to determine the relative success of the various methods. First, we will describe the data in the information set and the delineation between in-sample and out-of-sample data. Then the criteria for judging the forecasts will be discussed. After the three papers which present the attempts to forecast the series, a final paper discussing and comparing the results completes the competition.

The Data

The information set consists of seven series, each 100 observations in length. The seven variables were price and quantity series for two hypothetical, related agricultural products (to be referred to as feed and livestock), a price index for other goods, an income series, and a population series. The series were identified to the participants simply as price of good one (p_1), price of good two (p_2), quantity of good one (q_1), quantity of good two (q_2), price of other goods (p), income (y), and population (pop); the designations as feed and livestock were not provided to the participants.

The data generation process involved 150 observations. The price index of other goods and the income series were comprised of actual monthly data for the period from 1970:1 to 1982:6. The price index of other goods was the U.S. consumer price index (CPI) for food, and the income series was the index of industrial production. The population series was artificially generated using an exponential growth formula,

$$pop_t = 200e^{t/720} + N(0, .01) \qquad t = 1, \ldots, 150, \tag{1}$$

where $N(0, .01)$ represents a normal random variable with zero mean and variance equal to 0.01. This creates a population series with an

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average growth rate of approximately 1.7% per year to match the recent U.S. population growth rate. These three series were then used as exogenous variables in a four-equation structural stochastic model of supply and demand for "feed" and "livestock."

Referring to the "feed" series as series 1 and the livestock series as series 2, the two supply equations were specified as

$$(2)\quad \ln(q_{1t}) = 0.46 + 0.02\ln(p_{1t-1}) + 0.005\ln(p_{1t-2}) + 0.05\ln(p_{2t-1}) + 0.9\ln(q_{1t-1}) + N(0, .0064),$$

$$(3)\quad \ln(q_{2t}) = 4.6 - 0.1\ln(p_{1t-1}) - 0.05\ln(p_{1t-2}) + 0.3\ln(p_{2t-1}) + 0.1\ln(p_{2t-2}) + 0.05\ln(p_{2t-6}) - 0.003(q_{2t-4} - \bar{q}_2) + N(0, .0049).$$

The variable $\bar{q}_2$ represents the mean of q_{2t} and was set to 115 to represent the true mean; the sample mean was, in fact, quite close to 115. The demand equations were specified in inverse form as

$$(4)\quad \ln(p_{1t}) = 13.2 - 2.5\ln(q_{1t}) + 0.1\ln(q_{2t}) + 0.000001pop_t + 0.000002y_t + 0.0000015p_t + N(0, .0004),$$

$$(5)\quad \ln(p_{2t}) = 8.3 - 0.2\ln(q_{1t}) - 1.4\ln(q_{2t}) + 0.0000015pop_t\, 0.00001y_t + 0.000002p_t - 0.0000001t + N(0, .0016).$$

The series p_1, p_2, q_1, q_2, were initialized to 5, 2, 100, and 100, respectively, for the first six observations. The variable t is a linear time trend which began at 1. Beginning with observation 7, each period's quantities were generated using the supply equations. The prices were then generated by the demand equations. The process was continued until the data set consisted of 150 observations. The first 50 observations were then discarded to avoid excessive dependence on initial conditions.[1]

The participants received the first 90 of the remaining 100 observations. They were instructed to produce one-step-ahead, out-of-sample forecasts for observations 71 through 90 for the two price series. No other specific rules or guidelines for constructing the forecasts were provided. As many models as desired could be tried, and updating of coefficients was allowed. After each team selected a final forecasting model based on observations 1–90, out-of-sample forecasts for the final 10 observations (91–100) were constructed according to instructions and final coefficient estimates provided by each of the participants. Thus, the last 10 forecasts are truly out of sample because the participants could not change their models if the performance on the final 10 observations was poor.

The Criteria for Forecast Evaluation

The participants were told in advance that the forecasts would be evaluated by measures including mean-squared forecast error and ability in predicting turning points. The measures that were decided upon a priori were mean-squared forecast error, a Henriksson-Merton test that measures ability to predict the direction of revision, and the mean absolute percentage error. These three criteria captured attributes of many decision makers' loss functions.

Reference

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[1] The data are available from the authors on request in hardcopy format or on a diskette (if the diskette is supplied with the request).

Forecasting Multiple Time Series with Little Prior Information

David A. Bessler

It is difficult to do much in the way of prior specification when you have been handed seven series of data with a few-word description on each: series 1 is a price series, series 2 is a price series, series 3 is a quantity series corresponding to series 1, etc. Perhaps the data were generated as the outcome of a laboratory experiment, where a high degree of control on omitted variables was present, or maybe the data were generated as the outcome of a real-world economy where no control was present; finally, perhaps the data are from the real world but the person recording the data made mistakes entering series 3.

The amount of prior information which our competition group brings to this task, while meager, is perhaps no less than that brought to many econometric exercises (the experimental group excepted). As the list of possible explanatory variables which have been omitted from studies with secondary data is long, procedures built for summarizing regularities and forecasting are perhaps useful in both settings. Arguably, in both modeling environments "true" structure is unobtainable [as randomization is present in neither case (Rubin)]; demonstration of success (relative success) is obtained by comparing out-of-sample forecasts from alternative models.

The paper is presented in four sections. First the univariate properties of each series are studied. Simple measures on the autoregressive behavior of each series are presented. The product of this first section is a univariate model on each series. The second section considers the multivariate representation of these data. Three approaches to multivariate specification are taken. The third section of the paper considers the forecasting results from the alternative models. The final section of the paper offers a short discussion on forecasting with multiple economic time series.

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John L. Kling wrote the time-varying parameter, Bayesian vector autoregression program used in this paper. Cameshia Sims and Liisa Menzel provided word processing assistance.

Univariate Specifications

The univariate properties of these data are viewed from four vantage points: plots of the data; stationarity tests (Dickey and Fuller-type); autocorrelation and partial autocorrelation functions; and final prediction error (FPE) statistics. Because limitations were placed on our overall page offerings, no plots are presented here. Series referred to as one through seven are given as: price 1, price 2, quantity 1, quantity 2, price 3, income, and population, respectively. The first fifty data points are used for specification (model identification and initial estimation), data points fifty-one through seventy are used for out-of-sample forecasting. One-step-ahead forecasts of points seventy-one through ninety are then the twenty data points to be provided to the session organizers.

Plots (not shown here) of the series suggest that series 5, 6, and 7 are mean nonstationary; while series 1, 2, 3, and 4 do not show strong trends. These visual results are consistent with formal tests of nonstationarity, as given in unit root tests. Table 1 gives t-statistics on Dickey-Fuller and augmented Dickey-Fuller tests of nonstationarity. These are conducted on both levels and first differences. The null hypothesis in each case is that the original series is a random walk (nonstationary); a negative and significant t-statistic is required to reject nonstationarity in favor of stationarity. To our knowledge, critical values on these statistics have been explored by Monte Carlo methods for explicit models; we do not apply particular critical values but offer the tests as evidence supporting the general impression from the plots. Some may argue that all series need at least one difference, as the t-statistics on the augmented tests with levels exceed -3.0 in all cases. We are reluctant to pursue this strategy on series 2 and 4 and are close to indifferent with respect to series 1

Table 1. *t*-statistics on Tests for Stationarity

	$(1-B)^1$		$(1-B)^2$	
Series	DF[a]	ADF[b]	DF[c]	ADF[d]
1	−2.30	−1.73	−8.63	−5.56
2	−7.61	−1.58	−13.66	−6.17
3	−2.44	−1.76	−9.10	−6.17
4	−7.42	−2.07	−13.23	−5.43
5	+1.95	+1.21	−3.59	−3.03
6	+1.12	−0.13	−2.85	−2.50
7	+0.03	+0.81	−10.52	−7.58

[a] Dickey-Fuller (DF) test is on the coefficient $\hat{A}_1$, from regression $(1-B)X_t = \hat{A}_0 + \hat{A}_1 X_{t-1}$; where B is the lag operator. Failure to reject the null hypothesis ($A_1 = 0$) is consistent with the process X_t being generated as a random walk.
[b] The augmented Dickey-Fuller (ADF) test is of the same form as that given in the DF test except lags of the dependent variable as are specified using FPE on the right-hand side of each equation.
[c] Dickey-Fuller test on second differences is defined analogous to the test on first differences.
[d] Augmented test is defined similarly to that given in note.[b]

and 3. Tests on first differences (null hypothesis is that first differences have a unit root) show no sign of nonstationarity. Our preference is to model series 1, 2, 3, and 4 as stationary in levels and series 5, 6, and 7 as stationary in first differences.

Table 2 gives estimated autocorrelation and partial autocorrelations on each stationary-transformed variable. Using the Box and Jenkins' suggestion to study the tailing-off and cutting-off patterns in these functions, series 1, 3, 5, and 6 appear to be generated as autoregressions of low orders (one or two lags). Series 7 appears to be generated as a first-order moving-average process (its estimated partial autocorrelation function tails-off). Series 2 and 4 appear to have some higher-order lag characteristics (perhaps seasonality).

Table 3 gives estimated *FPE*-statistics on lags 1 through 8 on each series. Eight lags permits us to capture most of the large partial autocorrelations in series 2 and 4 and gives more than forty observations for subsequent fit.

The minimum *FPE*-statistics generally agree with the autoregressive orders suggested by the partial autocorrelation functions. Series 1 and 3 show minimum *FPE*-statistics at lags of two, which are the same orders suggested by the partial autocorrelations (table 2). *FPE*-statistics for series 2 and 4 are minimum at lags of 5, which again are consistent with the rather large partial autocorrelations on these series at these lags. Differences in series 5, 6, and 7 are generated by autoregressions of orders 1, 1, and 2, respectively.

Multivariate Representations

Three different approaches to building multivariate representations of these data are considered. First an unrestricted vector autoregression using (at most) five lags on each variable is built. This model is expected to perform rather badly. Our past experience with unrestricted VARs suggests their poor forecasting performance (Bessler and Kling).

Table 2. Estimated Autocorrelation and Partial Autocorrelation Functions on Stationarity-Transformed Data

	Lags							
Series Number	1	2	3	4	5	6	7	8
1 Auto	.75	.65	.54	.46	.40	.36	.30	.23
Partial	.75	.21	−.00	.00	.04	.03	−.03	−.07
2 Auto	−.23	.19	.24	−.19	.41	−.11	.14	−.03
Partial	−.23	.15	.34	−.11	.28	.01	.09	−.21
3 Auto	.70	.64	.55	.49	.35	.31	.22	.15
Partial	.70	.28	.06	.04	−.17	.03	−.07	−.04
4 Auto	−.22	.16	.24	−.29	.34	−.06	.07	−.00
Partial	−.22	.12	.31	−.23	.19	.06	.12	−.22
5 Auto	.43	.18	−.07	−.10	−.14	−.16	−.11	−.07
Partial	.43	−.01	−.17	−.02	−.07	−.10	−.00	−.02
6 Auto	.66	.43	.29	.20	.09	−.02	−.12	−.16
Partial	.66	−.01	.01	.02	−.10	−.08	−.10	−.03
7 Auto	−.46	−.05	.07	−.03	−.11	.20	−.17	.03
Partial	−.46	−.34	−.17	−.12	−.25	−.00	−.14	−.14

Note: Estimated standard errors at low lags are approximately $(50)^{-1/2} = .14$. Series 5, 6, and 7 are differenced.

Table 3. FPE-Statistics on Stationarity-Transformed Data

	Series						
Lag	1	2	3	4	5	6	7
0	2.200	.069	351.8	87.1	1.24	1.16	.024
1	0.927	.070	161.4	88.7	1.04*[a]	0.56*	.019
2	0.926*	.071	157.3*	91.4	1.08	0.59	.017*
3	0.972	.065	162.4	87.0	1.07	0.60	.018
4	1.021	.067	170.0	85.4	1.12	0.63	.019
5	1.071	.063*	168.5	85.3*	1.17	0.66	.018
6	1.112	.067	176.1	89.5	1.22	0.70	.019
7	1.167	.069	182.1	92.6	1.28	0.71	.019
8	1.210	.068	190.9	91.6	1.34	0.75	.020

[a] Asterisk indicates minimum value of FPE-loss. FPE loss is estimated over the first 50 observations on each series. Series 5, 6, and 7 are differenced.

Two types of restrictions on the multivariate representation are considered. First are explicit zero restrictions (variable i enters the autoregressive representation of variable j at lag k with a zero value). These are determined using the multivariate search procedure introduced by Hsiao. This approach has shown some promise in previous out-of-sample forecasting competitions (Kling and Bessler). Our second method for building a restricted VAR is to put a Litterman-type prior on an unrestricted model, allowing a small degree of parameter variation.

An unrestricted VAR is specified with the help of likelihood ratio statistics on the order of lags. These results are not reported in tabular form because of space limitations. We start at lag zero and test (upward) successive orders, $k = 1, 2, 3, 4$, and 5. The test is on the restriction that the parameter matrix at lag $k + 1$ is zero. The results suggest a first-order model, using a 1% significance level.

Table 4 gives a summary of lags selected using the Hsiao search procedure. No subset models are entertained. Interestingly, lags of both quantities (series 3 and 4) do not enter their corresponding price equations, equations (1) and (2). Equally puzzling is that lagged price of the first commodity does not enter the autoregressive representation of quantity of commodity 1 (series 1 does not enter the third equation, with lags). Finally, another puzzling result is that price of commodity 1 (series 1) enters the autoregressive representation of population.

Our final multivariate representation is an application of Litterman's Bayesian vector autoregression. It has been described in Litterman, and Doan and Litterman and applied in several settings, including Bessler and Kling. Our prior on each nondifferenced variable (series 1 through 4) is centered on a random walk—all coefficients in an unrestricted VAR have a prior mean of zero except those on the first lag of own series in each equation. Priors on each differenced variable (series 5, 6, and 7) are centered on zero.

Dispersion on each prior distribution is determined empirically by studying the logarithms of the determinant of the error covariance matrix on out-of-sample forecasts of points fifty-one through seventy for series 1 and 2 only. Settings on overall tightness, cross-equation tightness, and lag decay are specified and used to generate one-step-ahead forecast errors from a four-lag vector autoregression over this out-of-sample

Table 4. Lags on Each Variable in the Autoregressive Representation of Each Variable as Determined Using Hsiao's Search Procedure

	Equation						
Lags on Series	1	2	3	4 (lags)	5	6	7
1	1	5	0	5	0	0	3
2	0	4	0	4	0	1	0
3	0	0	1	0	0	0	0
4	0	0	0	5	0	0	0
5	3	0	3	0	1	4	0
6	1	2	0	5	0	1	0
7	0	0	0	3	1	1	2

Note: Autoregressions were selected applying the multiple search procedure described in Hsiao. This procedure was applied recursively to each series on data points 7–50.

Table 5. Forecast Results (Log Determinant) from Alternative Settings on Overall Tightness (λ), Cross-Equation Tightness (γ_2), Harmonic Decay (Decay), and Time Variation (T.V.)

T.V. = .00; decay = .00

	λ		
γ_2	.00	.50	1.00
.00	−2.41	−3.43	−3.44
.50	−2.42	−3.37	−3.22
1.00	−2.45	−3.13	−3.09

T.V. = .01; decay = .00

	λ		
γ_2	.00	.50	1.00
.00	−2.44	−3.43	−3.44
.50	−2.45	−3.37	−3.21
1.00	−2.49	−3.14	−3.10

T.V. = .00; decay = 1.0

	λ		
γ_2	.00	.50	1.00
.00	−2.39	−3.35	−3.41
.00	−2.40	−3.50	−3.49
1.00	−2.41	−3.37	−3.35

T.V. = .01; decay = 1.0

	λ		
γ_2	.00	.50	1.00
.00	−2.42	−3.35	−3.41
.50	−2.43	−3.52	−3.51
1.00	−2.45	−3.39	−3.36

Note: The reader should consult Wolff and Litterman for details on the general form of the model specified here. Briefly, we study estimates of parameters using Theil's mixed estimator, where the parameter, β, is specified to depend on λ, an overall tightness parameter; γ_1, a decay parameter; γ_2, a parameter on cross-equation influence; and T.V., a parameter governing the degree of time variation permitted.

period. Values of these parameters which give lowest log determinant measures are then used as our priors for forecasting over data points seventy-one through ninety. Included in this search is a small degree of parameter variation following the procedure introduced by Wolff.

Table 5 gives the log determinant values from out-of-sample forecasts associated with various settings on the priors and degree of parameter variation. Note that some parameter variation appears to be beneficial. The log determinant measures on the two no-time variation panels lie above panels with a small degree of time variation (our setting on time variation (.00 and .01) were selected following the recommendations in Wolff. So too, some decay appears beneficial; as the lowest log determinant measure is achieved under a decay parameter of 1.0. Of course, more extensive searches over the four-dimension space may sculpt a more interesting figure. The Bayesian parameter settings used for our forecasting competition are as follows: overall tightness = .6; cross-equation tightness = .4; decay = 1.0; and time variation = .01.

Results

Table 6 gives root-mean-squared error measures on forecasts over periods fifty-one through seventy and seventy-one through ninety. The most striking result in the table is that the univariate models appear to do quite well.

Discussion

Our results agree with those found in earlier forecasting competitions, where forecasts of prices from vector autoregressions do not show much improvement over forecasts from univariate representations of prices. Kling and Bessler write (with respect to hog prices): "the price series do not seem amenable to better forecasts through the additional information which the VARs incorporate." Perhaps this is a funda-

Table 6. Root-Mean-Squared Error (RMSE) Out-of-Sample Forecast Performance Metrics on BVAR, RVAR, UVAR, and Univariate Autoregressions, Observations 51–70 and 71–90

	Series 1	Series 2
Model	*(RMSE)*[b]	
UNIV	.710/.752	.257/.353
UVAR	.818/.796	.222/.496
RVAR	.877/.757	.238/.417
BVAR	.745/.767	.238/.441

[a] BVAR is a four-leg Bayesian vector autoregression with time variation; RVAR is a restricted vector autoregression with zero restrictions determined using Hsiao's search procedure; UVAR is an unrestricted vector autoregression (no zero restrictions); and UNIV is a univariate autoregression with lags determined by applying FPE to each series. In all cases series 5, 6, and 7 were first differenced.
[b] The numerator gives RMSE's on forecasts of observation 51 through 70; while the denominator gives RMSE's on forecasts of observations 71 through 90.

mental regularity of market-generated secondary data.

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Forecasts from a State Space Multivariate Time-Series Model

Keith R. Criddle and Arthur M. Havenner

Several recent papers have presented theoretical extensions and applications of the multivariate time-series modeling technique described in Aoki. Examples include some of the papers with which we have been personally involved. Aoki and Havenner (1989a) develop the relationship between system-theoretic time series (STTS) and two kindred techniques. Aoki and Havenner (1989b) is a comprehensive review of STTS with extensions. Havenner and Aoki (1988a) present an instrumental variables interpretation of STTS. Havenner and Aoki (1988c) develop the connection between STTS and traditional econometrics. Havenner and Aoki (1988b) extend STTS to nonstationary time series. Havenner and Criddle recast STTS in an autocorrelation rather than autocovariance framework, contrast this autocorrelation version of STTS with a multivariate time series model developed by Akaike, and present an application to California cattle inventories and beef prices. Cerchi and Havenner apply STTS to stock prices. Criddle and Havenner (1989a, b) present applications of STTS to forecasting changes in fish populations. Havenner and Tracy compare the performance of STTS and hydrological models of the Eel River watershed. Dorfman and Havenner develop a Bayesian approach to STTS.

This paper will present a detailed discussion of model specification at an applied rather than conceptual level. Section one gives a brief overview of STTS. The second section specifies, develops, and evaluates STTS forecasts of the two price series explained in McIntosh and Dorfman. We discuss the performance of STTS in this competition in the final section.

System-Theoretic Time Series

Exploiting a unique arrangement of autocovariances, the system theory approach is able to specify the lag structure of the model based on the rank of an estimated Hankel correlation matrix. This Hankel matrix of autocorrelations is obtained as the expectation of the outer product of the observed series with itself lagged. The usual carriers of past information, lagged observations, and moving-average errors are combined in a set of state variables, which are minimum sufficient statistics for the past history of the series. Robustness with regard to model specification is obtained by forming these states as specific linear combinations of the observed series. Because of the way in which the states are formed, a largely nonsubjective search can be conducted over possible models while assuring consistency of included coefficients even if model order is misspecified. [For a development of these attributes, see Aoki and Havenner (1989b), Havenner & Aoki (1988b, c), as well as the original Aoki reference.]

The state space model consists of two matrix equations:

$$z_{t+1/t} = Az_{t/t-1} + Be_t \tag{1}$$

$$y_t = Cz_{t/t-1} + e_t. \tag{2}$$

There are T observations on each of m stochastic series in y. Equation (1) relates the vector of scaled centered observations, y_t, to the n-element vector of unobservable states, $z_{t/t-1}$ through the $m \times n$ matrix C. The number of states n depends on the degree to which the component series follow common processes and on the complexity of the underlying dynamics, with higher-order dynamics resulting in increased states. Motion of the state variables is described by equation (2). Because the number of states is to be determined, and because it is always possible to define new elements equal to the lag of other elements in the state vector to reach any lag desired, there is no loss of generality in assuming that the state equation is first order (Aoki or Aoki and Havenner 1989b).

The $n \times n$ matrix A relates the state variables to each other through time, while B is an $n \times$

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m matrix of Kalman filter updates included to incorporate current innovations into the forecasts of the states. Given stationarity, the model can always be formulated so that the m element error vector e_t is serially uncorrelated and centered on zero, with a constant contemporaneous covariance matrix denoted by Ψ. Aoki demonstrates that the optimal states are linear combinations of the observed residuals so that equations (1) and (2) can be written with the same error. When the data are centered and scaled by their standard deviations, the autocovariances of the transformed data are also autocorrelations of the original data; see Havenner and Criddle for an analysis of the effect of this scaling on the properties of the procedure.

The sample Hankel autocorrelation matrix is

$$(3)\quad H = \begin{vmatrix} \Gamma_1 & \Gamma_2 & \Gamma_3 & \dots & \Gamma_N \\ \Gamma_2 & \Gamma_3 & & & \\ \Gamma_3 & & & & \\ \cdot & & & & \\ \cdot & & & & \\ \Gamma_N & & \dots & & \Gamma_{2N-1} \end{vmatrix},$$

where the Γ_i are the $m \times m$ sample autocorrelation matrices

$$(4)\quad \Gamma_i = Ey_{t+i}y_t^T \qquad i = 0, 1, 2, \dots, 2N-1,$$

and $2N - 1$ is the maximally distant autocorrelation to be modeled. In practice, selection of the lag parameter N involves trading off errors in the estimated sample autocorrelations at long lags against the risk of not capturing all of the important lags. All modeling procedures require specification of such a parameter, whether explicitly, as in this case and structural modeling, or implicitly, as when inspecting the autocorrelation functions in a more traditional time-series setting. One of the difficulties in specifying multivariate time-series models is that the order of the determinantal polynomial in the lag operator for any individual series has a maximum equal to the product of the system lag and the number of series, so that N may be relatively small but with complex interactions between series.

By the Kronecker theorem, the rank of the population counterpart of the sample Hankel matrix is the number of states necessary to characterize the system (see Havenner & Aoki 1988a for an intuitive justification of this result). The singular value decomposition is a computationally accurate method of determining the rank of the sample Hankel matrix

$$(5)\quad H = U\Sigma V^T = U\Sigma^{1/2}\Sigma^{1/2}V^T,$$

where Σ is a diagonal matrix of estimated singular values, pre- and postmultiplied by the orthonormal singular vectors U and V, $U^T U = I$, $V^T V = I$. If the autocorrelations were observed exactly, the redundant singular values would be zero. Because the autocorrelations are determined from the data, there is sampling error in the estimated Hankel matrix and in the singular values derived from it. Aoki and Havenner (1989a) list several criteria which can be used to estimate consistently the cutoff point when the estimated singular values are ordered from largest to smallest. Selection of the estimated rank of H and the required number of states, n^*, so that σ_{n^*+1}/σ_1 of order $T^{-1/2}$, is analogous to a criterion based on condition number.

Estimates of the dynamic coefficient matrix A, and the observation-state mapping matrix C, can be obtained from equations (1) and (2), conditional on n^*.

The first block row of the sample Hankel matrix, denoted H_{1*} is used to estimate C

$$(6)\quad C = H_{1*}V\Sigma^{-1/2},$$

(see Aoki). Define $\mathcal{H}$ as the matrix formed by shifting the blocks of the original sample Hankel matrix left one block column and filling in on the right. Then an estimate of A is

$$(7)\quad A = \Sigma^{-1/2}U^T\mathcal{H}V\Sigma^{-1/2}.$$

The first block column of the sample Hankel matrix, denoted H_{*1} is used to estimate Ω,

$$(8)\quad \Omega = \Sigma^{-1/2}U^T H_{*1},$$

a covariance matrix necessary for estimation of B. An estimate of B can be obtained from the joint solution of three matrix equations which minimizes Ξ, the contemporaneous covariance of the states:

$$(9)\quad \Xi = A\,\Xi A^T + B\,\Psi B^T,$$

$$(10)\quad \Gamma_0 = C\,\Xi C^T + \Psi,$$

$$(11)\quad \Omega = A\,\Xi C^T + B\Psi.$$

Equations (9), (10), and (11) can be solved for estimates of Ξ, Ψ, and B conditional on estimates of A, Γ_0, Ω, and C both by iterative and noniterative methods (see Aoki).

With estimates of A, B, C, Ω, and an estimate of the initial state vector z_0, equations (1) and (2) can be solved for in and out of sample forecasts.

Models

In the context of this competition, and in many applications, the single most important requirement of a model is that it produce accurate forecasts. Although economic theory suggests that income, price of other goods, population, and own quantity may contribute to an understanding of price, it is by no means assured that they will contribute to improved forecasts of P_1 and P_2.

Plots of the data show trends in income, price of other goods, and population, but not in Q_1 or Q_2, and not in either price series to be forecast. If we were to include income, price of other goods, or population, any effects of these other variables would have to offset each other's trend. Further, the price forecasts would then be conditional on forecasts of the exogenous variables. Accordingly, we decided to ignore these other variables in specification of our model.

Simple structural models of price, given quantity, were very successful at explaining the observed data but were not used because of our interest in unconditional forecasts of price. Adoption of the simple structural model merely changes focus from forecasting the price series to obtaining forecasts of the quantity series to be used to generate forecasts of the price series via the estimated structural relationship.

On the basis of these considerations, three models were selected for further analysis:

(*i*) Univariate P_1
Univariate P_2,
(*ii*) Bivariate P_1, P_2,
(*iii*) Multivariate P_1, P_2, Q_1, Q_2.

The number of state variables required to characterize the system depends on the complexity of the processes and on the presence of common dynamics. The univariate models are simple and often very successful, especially if dynamics are low order or the time series are independent. By exploiting common factors, multivariate models may produce better forecasts when the time series are not independent.

Determination of the number of states required to represent the processes entails a conditionally one-dimensional search when there is reasonable prior information on the lag parameter N. When the lag length is unknown, as is typical, the specification search is two dimensional in N and n^*. Given a choice of N (perhaps as an element of a grid search), there typically are no more than two or three choices of n^* which satisfy the condition number criterion. The preferred model specification is determined on the basis of in-sample mean-squared error. In-sample mean-squared errors for all of the models that we considered are reported in table 1.

Univariate models of P_1 with $N = 1, 2, 3, 4$, 5, and 6 performed similarly in-sample. We selected the simplest model: $N = 1$, $n^* = 1$. For the univariate P_2 model, $N = 3$, $n^* = 3$ was the preferred specification, although models with $N = 4$, 6, and 12 were nearly as successful.

Bivariate models of P_1 and P_2 for $N = 2$, 3, 4, and 6 were fairly similar, as would be anticipated from the results of the univariate models. On the basis of minimum mean-squared error, the preferred specifications for the bivariate P_1, P_2 model are $N = 6$, $n^* = 3$, and $N = 6$, $n^* = 4$. Because the number of states required to model the bivariate series was less than or equal to the number of states required to model the series individually, P_1 and P_2 may share common dynamics. The bivariate models were characterized by smaller in-sample mean-squared errors for both price series than the corresponding univariate models.

Multivariate P_1, P_2, Q_1, Q_2 models performed poorly except for $N = 3$, $n^* = 3$, which produced a very slight (0.01) reduction in mean-squared errors for the P_1 series while matching the bivariate P_2 series mean-squared errors. While the total number of state variables was not increased by adding Q_1 and Q_2 to the model, their inclusion doubled the number of coefficients to be estimated, and, given the performance of all multivariate P_1, P_2, Q_1, Q_2 models except the one, we preferred the bivariate specification over this model.

On the basis of in-sample mean-squared error, the two bivariate models (P_1, P_2 with $N = 6$ and $n^* = 3$, and $n^* = 4$) appeared marginally more promising than the univariate models. While the additional state in the second model does not

Table 1. Model Specification: Mean-Squared Error

	Univariate		Bivariate		Tetravariate
N	1	3	6	6	3
n^*	1	3	3	4	3
Coefficients	4	10	18	23	37
P_1	.67		.63	.62	.61
P_2		.05	.04	.04	.04
Q_1					130.42
Q_2					53.58

seem important, both models were estimated and their out-of-sample performance examined. Because the model with three states is strictly nested in the four-state model, common coefficients are identical. The 3×3 upper left-hand block of the state dynamics matrix, A, for the model with four states is the A matrix for the three-state model,

$$A$$

$$\begin{array}{rrrr}
0.857 & -0.021 & 0.007 & 0.050 \\
0.027 & -0.801 & 0.583 & -0.056 \\
-0.009 & -0.344 & -0.543 & -0.117 \\
 & & & \\
0.028 & 0.313 & 0.259 & 0.505
\end{array}$$

Similarly, the 2×3 left-hand submatrix of the four-state mapping matrix, C, is the three-state C matrix,

$$C$$

$$\begin{array}{rrrr}
-1.120 & -0.111 & -0.081 & 0.186 \\
-0.109 & 0.100 & 0.144 & 0.002
\end{array}$$

While the 3×2 upper submatrix of the four-state covariance of the states and observations, Ω, is the three-state Ω,

$$\Omega$$

$$\begin{array}{rr}
-1.131 & -0.082 \\
0.070 & 0.025 \\
0.049 & -0.184 \\
 & \\
0.188 & -0.030
\end{array}$$

The unconditional covariance matrix Γ_0 is shared by all of the bivariate models,

$$\Gamma_0$$

$$\begin{array}{rr}
1.694 & 0.093 \\
0.093 & 0.069
\end{array}$$

Although the remaining coefficient and covariance matrices are not nested, they are closely related

$$B \qquad\qquad\qquad B$$

$$\begin{array}{rr}
-0.547 & -0.026 \\
0.025 & 1.101 \\
0.030 & -2.847
\end{array}
\qquad
\begin{array}{rr}
-0.588 & -0.058 \\
-0.004 & 0.969 \\
0.055 & -2.846 \\
0.302 & -1.805
\end{array}$$

$$\Psi \qquad\qquad\qquad \Psi$$

$$\begin{array}{rr}
0.694 & 0.015 \\
0.015 & 0.041
\end{array}
\qquad
\begin{array}{rr}
0.626 & 0.013 \\
0.013 & 0.042
\end{array}$$

$$\Xi$$

$$\begin{array}{rrr}
0.782 & 0.012 & 0.006 \\
0.012 & 0.912 & -0.083 \\
0.006 & -0.083 & 0.582
\end{array}$$

$$\Xi$$

$$\begin{array}{rrrr}
0.786 & 0.025 & 0.005 & -0.109 \\
0.025 & 0.874 & -0.098 & -0.137 \\
0.005 & -0.098 & 0.580 & 0.057 \\
-0.109 & -0.137 & 0.057 & 0.349
\end{array}$$

The out of sample performance of the three-state model was slightly better than that of the four-state model (table 2). Although the model was not exceptionally successful at forecasting P_1 or P_2, the model was accurate at predicting direction. The Henrikson-Merton test statistic indicates that our model achieved a 99.4% confidence level in matching actual turning points in our joint forecasts of the two price series. Accordingly, given the information available, we choose the bivariate model with $N = 6$ and $n^* = 3$ as our best model.

In Retrospect

It is perhaps fair to summarize our performance in the competition (see Dorfman and McIntosh)

Table 2. Model Validation: Summary Statistics

	$n^* = 3$	$n^* = 4$
In sample		
MSE	0.633	0.622
	0.036	0.037
Percent error	19.2	19.0
	9.2	9.3
R^2	0.626	0.633
	0.479	0.466
D-W	1.946	2.174
	2.072	2.028
Out of sample		
MSE	0.735	0.821
	0.141	0.142
Percent error	22.8	24.1
	17.7	17.8
R^2	0.222	0.131
	0.411	0.410
D-W	2.031	2.359
	1.825	1.847

as having produced clearly the best P_2 forecasts and equally clearly the worst P_1 forecasts, and from a joint model no less. It would be useful to understand how this situation could occur. We do not, but three sources of error present themselves: errors in the modeling procedure, incorrect use of prior information, and as always, sampling error.

Procedural Errors

The first thing to consider is flaws in the state space modeling procedure employed, either inherent or as we applied it. In the latter category, after learning the nature of the true model, we realized that we had not even considered two separate bivariate models, each with one price and quantity. Running such a pair of models, as occurred after the fact, results in mean-squared errors very similar to those of the selected model in sample, but much lower on the twenty observations from seventy-one to ninety. While our selected model deteriorated out of sample, this formulation improves. (We do not have the last ten observations, and so cannot evaluate any of the models over this interval.) Similarly, there may be other potentially valid models that simply did not occur to us.

Selection of a particular model from the set of plausible models is a common problem in time-series analysis.[1] While the states in the procedure described above have been chosen to provide a measure of robustness with respect to models within a particular set, e.g., of given series and lag parameter, it is not possible to make the choice robust over models as different as two univariate (price) specifications versus a single tetravariate (two prices, two quantities) specification. Econometricians naturally wish to formalize this decision in a statistical test, but the pattern recognition used informally in assessing graphical output and summary statistics is difficult to capture in a single test statistic. In addition, there is probably a natural indeterminacy that is removed only by arbitrary choice. For example, we use out-of-sample mean-squared error to validate the model choice from in-sample information, while others formally or informally optimize in the out-of-sample periods. We are not aware of definitive arguments favoring one procedure over the other. In this case, our out-of-sample mean-squared errors for the selected model increased to 0.736 from 0.632 for the first series and to 0.141 from 0.036 for the second series, over the twenty observations from seventy-one to ninety. The mean-squared errors of the univariate models decreased out of sample, as did those of the two bivariate price-quantity models.

Prior Information

While time-series analysis is relatively free of specific prior information, nevertheless it is typical to know the names and characteristics of the series being modeled. In this case, triangularity would probably have been imposed by all modelers had the names of the price series been disclosed. In addition, clues regarding seasonality would have been available given the frequency and nature of the data.

We were surprised that the errors in the data-generating process were uncorrelated across equations. While uncorrelated errors are convenient for ordinary least squares estimation, they are probably not typical for data of this type and would be expected to importantly influence the outcome.

Sampling Error

This experiment is but one realization, providing just one set of outcomes. Apart from attempting to average over the true model characteristics, one can imagine running the experiment repeatedly, with different error draws and possibly very different results. Of course, it would be so much work that no one would participate. Sampling error may well be an important consideration in a contest of this sort when the models are all so close in terms of in-sample summary statistics.[2] This is particularly apparent when we examine our univariate model forecasts for observations seventy-one to ninety: the mean-squared errors are 0.5535 and 0.1296 for the two price series (better than any of the contest models for these observations), when the specifications cannot possibly be consistent with what we know to be the true model without major cancellation of factors.

Finally, lest this postmortem sound like an

[1] Combining model forecasts in a logically consistent manner is more easily accomplished under Bayesian assumptions than with the classical assumptions underlying our estimates.

[2] While this sort of sampling error is typical of actual data, it does complicate the evaluation of methods.

apology or a criticism of the experiment, let us note that these exercises are in our opinion invaluable. We have always made it a point to include applications with out-of-sample forecasts, being devout believers in the importance of falsifiability. While one draw is all the information that you get, over time the evidence builds up, and a general conclusion regarding modeling procedures emerges along with mandated refinements in method.

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Forecasts from a Nonparametric Approach: ACE

Peter Berck and James A. Chalfant

Optimal forecasting requires both a choice of variables to include and determination of the appropriate functional form. The alternating conditional expectations (ACE) method (Breiman and Friedman) is a general functional form. It is not a philosophy of model testing and revision like Box-Jenkins. It does not include a model selection algorithm like the state space models do. ACE does internally make use of the idea of cross validation, which is closely related to prediction error. We have carried that empirical philosophy over to the area of model selection and combined strongly held economic priors with a search for models with low values of the final prediction error criterion. Our model selection strategy was to consider only those models with homogeneity and per capita quantities. Because our interest is in prediction, we considered only those models in which the regressors would be predetermined.

The ACE Algorithm

Consider the model

$$\phi(y) = \sum_{i=1}^{K} \theta_i(X_i) + e,$$

where y is the dependent variable, each of the K variables X_i is an explanatory variable, and e is the residual. With ordinary least squares, the transformations ϕ and θ_i are linear; logarithms or Box-Cox transformations are often substituted in an attempt to strengthen the empirical relationship between y and the X_i vectors. ACE generalizes this process by substituting data-smooths for a parametric transformation and finds the optimal transformations to minimize unexplained variation in $\phi(y)$.

Breiman and Friedman introduced ACE and provided the proofs for the algorithm's convergence to the optimal transformations. They also showed that the algorithm produces the maximal correlation between y and x in the bivariate case. The output from the procedure is a series of plots of $\phi(y)$ against y and of each $\theta_i(X_i)$ against X_i. As long as additivity on the right-hand side is acceptable, ACE provides a general approach to discovering the functional form with which a regressor should enter an equation. After inspection of the plots, one is free to specify a parametric functional form that mimics the observed plots, although this is not necessary.

Friedman and Stuetzle defined a smoother as a procedure applied to two series $(X_1, y_1), \ldots, (X_n, y_n)$ that decomposes observations y_t according to

$$y_t = s(X_t) + e_t \quad t = 1, \ldots, n,$$

where $s(\cdot)$ is any smooth function. Friedman describes a smoother as a procedure for estimating the condition expectation of Y given $X = x$. Regression models are examples, as are regression models that use a subset of the data (e.g., Tibshirani), called a window, around each observation. ACE makes use of the Super Smoother of Friedman and Stuetzle, where the smooth is based on a local linear regression and a window size chosen by cross validation.

Predictions from ACE are made using ACEPRED. It estimates ϕ^{-1} by smoothing y on the sum of the transformed x's.

An Example

To illustrate the use of ACE,[1] suppose one has available observations on a random variable $X \sim N(0, 1)$ and $Y = X^2$. Even though there is a perfect relationship between these two random variables, a linear regression of Y on X would suggest no relationship, i.e., a horizontal regression line.

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The authors wish to thank Angie Erickson and Richard Gray.

[1] The authors thank Richard Carson for suggesting this example.

By examining the relationship between Y and X in only a neighborhood of each observation and thereby allowing for nonlinear and nonmonotonic transformations, ACE is able to detect that the optimal transformations are $\phi(y) = Y$ and $\theta(X) = X^2$, as shown in the top portion of figure 1. These plots are based on 200 data points generated as described above.

ACE also detects regime shifts. Suppose

$$Y = \begin{cases} X^2 & |X| \leq 1 \\ 1 & \text{otherwise.} \end{cases}$$

Given 200 observations for Y and, again, $X \sim N(0, 1)$, ACE obtains the plots in the lower part of figure 1.

Data Transformations

We used observations one through seventy and the seven variables provided, denoted by $P1$, $P2$, $Q1$, $Q2$, P, Y, and POP. We were not informed as to the true model or even that the true model concerned an agricultural market. Nevertheless, we assumed the data were from a sensible economic model and imposed the usual restrictions on the models. To begin with, we assumed that P was an appropriate deflator for this model and that the true relationship would be in real terms. Similarly, we assumed that the true demand relationship would involve quantities per capita. To implement these reasonable restrictions from economic theory, we produced per capita quantities $q_1 = Q1/POP$ and $q_2 = Q2/POP$. We then obtained a real per capita income measure $y = Y/(POP \cdot P)$ and real prices $p1 = P1/P$ and $p2 = P2/P$. These restrictions left us with five variables entering our model with unknown numbers of lags.

With our five-variable data set, we took an empirical approach—we considered all possible linear regressions of $p1$ and $p2$ on up to four lags of $p1$, $p2$, $q1$, $q2$, and y, giving us twenty

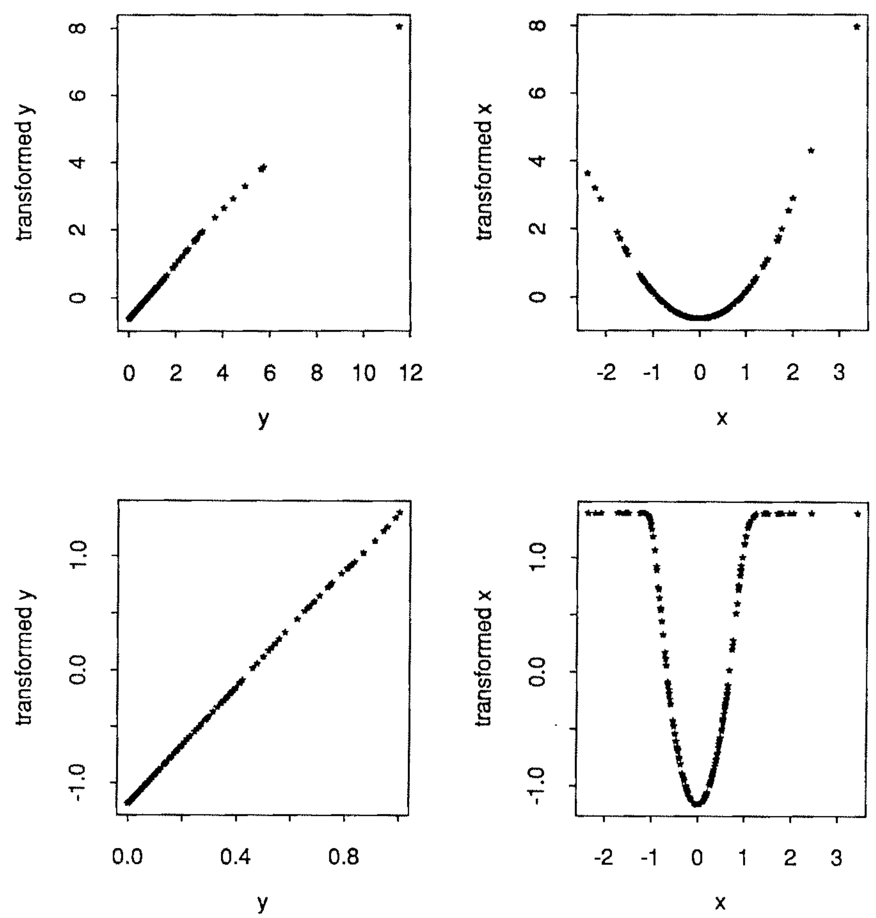

Figure 1. Example transformations using ACE—y and x

potential regressors. Four was, of course, an arbitrary choice made without knowledge of the periodicity of the problem (monthly, quarterly, etc.). We then found the collection of regressors that minimized the final prediction error (FPE) criterion.

For $p1$, the regressors were

$$p1(t-1), p2(t-4), y(t-2), y(t-3), y(t-4).$$

For $p2$, the regressors were

$$p1(t-1), p1(t-4), q1(t-1), y(t-1), p2(t-1), p2(t-2), p2(t-3), q2(t-2), q2(t-3), q2(t-4).$$

The parentheses indicate the length of the lags. We fit these two models using ACE and calculated the root mean-squared errors (*RMSE*) of our predictions for observations seventy-one through ninety. To compensate for possible overfitting, we then searched for models with smaller numbers of regressors that predicted out of sample equally well. For both models, we found that it was possible to reduce the RMSE for observations seventy-one through ninety by deleting some regressors. For instance, we examined the best four variable model for $p1$, using the FPE results, and so on, seeking a "smaller" model with better out-of-sample predictions.

For $p1$, we settled on three regressors—$p1(t-1)$, $p1(t-2)$, and $y(t-3)$. Six were optimal for $p2$—$p1(t-1)$, $y(t-1)$, $q2(t-1)$, $q2(t-4)$, $p1(t-4)$, and $q2(t-3)$. Each regressor is believed to use up about four degrees of freedom with ACE, so trimming the number of regressors can have a dramatic impact on the precision of the estimates. Breiman and Friedman use R^2, the only statistic calculated by ACE, for this purpose.

The rules of the competition specified prediction of the nominal prices as the goal. We tried two different approaches: (*a*) nominal ACE—ACEing the nominal price on the chosen regressors and the price index and (*b*) real ACE—predicting the price index in an autoregressive model and multiplying the real ACE predictions by the price index predictions. We chose among these methods based upon *RMSE* prediction error. As a (depressing) check on our work, we also estimated an autoregressive model for $P1$ and $P2$.

Our second prediction method required an estimate of the price level, which we made with a simple autoregressive model. No alternate models were considered, and none of the standard tests were run. The price level, P, was predicted by

$$P_t = \underset{(.69)}{-1.29} + \underset{(106)}{1.013}\, P_{t-1} + \underset{(4.22)}{.46}\, E_{t-1}$$

with an R^2 of .9982. The numbers in parenthesis are t-statistics. The prediction error from this equation was on the order of 1%—more than good enough for our purposes.

For $P1$, the nominal ACE method had an *RMSE* of 1.34; using real ACE and multiplying by the price index prediction gave .745 as did the simple autoregressive method. We chose the real ACE method for $P1$.

For $P2$, the *RMSE*s were .392 for nominal ACE, .436 for the autoregressive model, and .572 for real ACE. We selected the method of using the nominal $P2$ in ACE directly, adding the lagged price level as a seventh right-hand-side variable.

The Transformations

Since the detailed numerical results are documented in Dorfman and McIntosh, we will focus on the plotted transformations found by ACE. Figure 2 contains the results for the variable $p1$ with the three right-hand-side variables $p1(t-1)$, $p1(t-2)$, and $y(t-3)$.

In the upper left of the figure, values of $\phi(y)$ are plotted on the vertical axis against those of y on the horizontal axis. For the most part, something like a logarithmic transformation is suggested, as the points appear to lie along a curve which is concave. The more horizontal portion is harder to interpret; for this region, the best fit is obtained by mapping all values of y to essentially the same $\phi(y)$, around -0.9.

The plots for the three right-hand-side variables should be interpreted similarly. The relationship between $\theta(p1(t-1))$ and $p1(t-1)$ is essentially linear, although the smallest values are not too informative, in the sense that a range of lagged values of $p1$ yields nearly the same value of $\theta(p1(t-1))$. To aid in interpreting the results, note that an increase in lagged price, from 0.03 to 0.04, appears to increase $\theta(p1(t-1))$, which is added to the dependent variable $\phi(y)$, by around 0.5. When so desired, this could be transformed into a corresponding change in y using the first plot.

A plot of the optimal transformation of $p1(t-2)$ shows a highly nonlinear relationship.

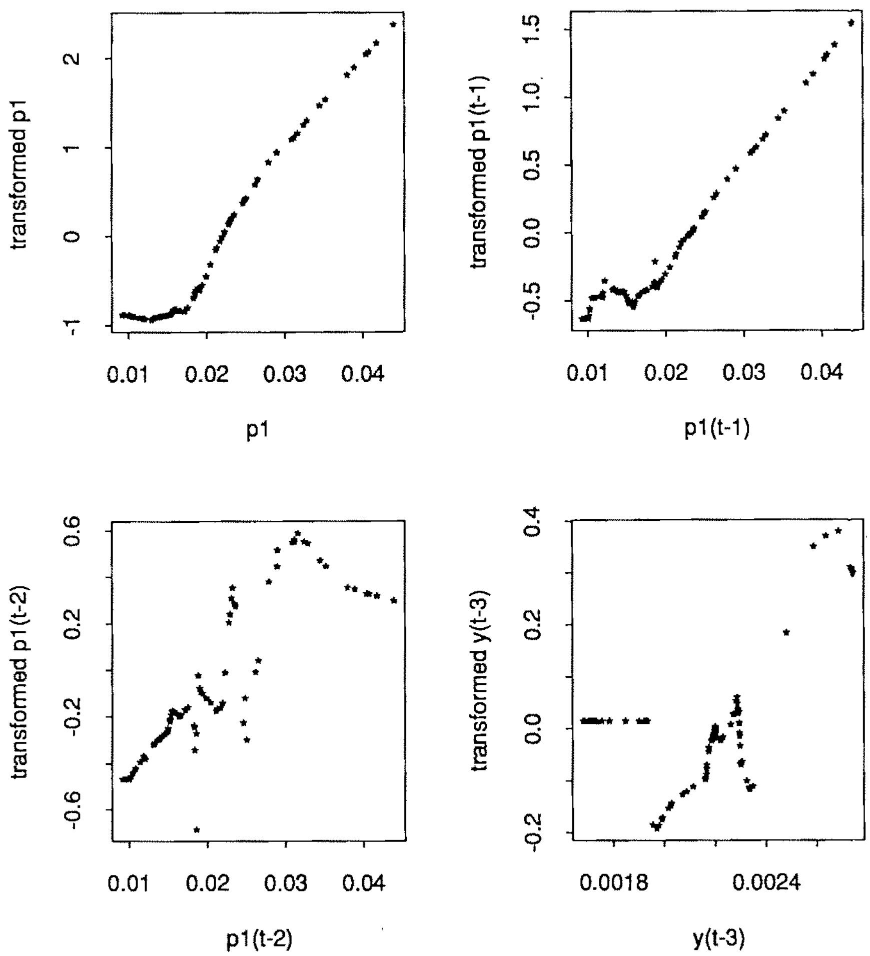

Figure 2. Optimal transformation using ACE—$p1$

Values of this variable below around 0.03 are characterized by a positive association with $\phi(y)$—the transformation $\theta(p1(t-2))$ is increasing, for the most part; values above 0.03 are characterized by a decreasing transformation.

As noted by Breiman and Friedman, ACE can find very nonlinear relationships where the association between two variables is actually rather weak. In situations where the correct variables to include are in doubt, therefore, there is some danger of overfitting. When this is not the problem, plots such as this one illustrate a gain that ACE affords over regression methods based on an arbitrarily chosen parametric transformation—nonmonotonic transformations are permitted with ACE, while these are almost always ruled out with parametric approaches, for instance, with a Box-Cox transformation.

Summary and Conclusions

We used a nonparametric regression technique, ACE, to estimate the optimal transformations of the prices for which forecasts were desired and the variables on which they were based. Our artificial example illustrates the power of the technique, as do the examples of Breiman and Friedman. For the present case, the optimal transformations appear to be both nonlinear and, in some cases, nonmonotonic. The common practice of double-log or Box-Cox regressions, while often good approximations, do not admit the latter possibility.

Two applications for ACE are suggested any time the functional form is in doubt. First, plots such as those we obtained could be used to suggest the appropriate parametric transformation. For instance, the monotonicity assumption could

be examined. Second, models such as the double-log model can be tested. ACE provides a diagnostic check in the following manner. Suppose that the true model is believed to be $\ln y_t = \beta \ln X_t + \varepsilon_t$. Applying ACE to $\ln y_t$ and $\ln X_t$ should reveal that the optimal transformation of each variable is linear if the hypothesis is true. If an alternative model were true, ACE would transform the logged data to better mimic that relationship.

With regard to the competition, we were at first impressed with the performance of heuristic, ad hoc, model selection, combined with the ACE method. Havenner and Criddle's state space methods are appealing because they avoid the ad hoc model selection, so it was impressive to see a series of (incorrect, it turned out) economic assumptions and blatant empiricism outpredict the state space model for $P1$. On further reflection, we note that even a very simple autoregressive model predicts quite well and wonder what kind of *RMSE*s would have been turned in by an experienced user of the Box-Jenkins techniques.

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Results of a Price Forecasting Competition

Jeffrey H. Dorfman and Christopher S. McIntosh

This paper evaluates the results of the price-forecasting competition in which three teams of econometricians attempted to forecast two time series of unidentified prices. The price series were presented as part of an artificial data set containing a total of seven variables and 100 observations. The seven variables were identified as price of good one, price of good two, quantity of good one, price of other goods, income, and population. The participants were sent the first 90 of the 100 observations and asked to construct one-step-ahead forecasts for the final twenty observations in the data sets they received. Forecasts for the final ten observations were then generated according to an *ex ante* rule so that the last ten forecasts would truly be out of sample. As in the introduction, the two price series will be referred to as the prices of "feed" ($p1$) and "livestock" ($p2$).

The Forecasts

The three teams of forecasters were Peter Berck and James Chalfant, David Bessler, and Keith Criddle and Arthur Havenner. The methods employed by each are described in detail in preceding papers and are only briefly described here.

Berck and Chalfant employed a statistical package shown as ACE which, when given a dependent variable, y, and a set of independent variables, X, searches for the $\phi = g(y)$ and $\theta = h(X)$ that maximizes the correlation coefficient between θ and ϕ. It then uses these transformations of the variables to forecast ϕ and recover a forecast of y by applying the inverse transformation $\hat{y} = g^{-1}(\hat{\phi})$. To forecast the price of feed, Berck and Chalfant included one-period and two-period lagged values of the price of feed deflated by the price of other goods and real per capita income lagged three times as independent variables. They used the deflated price of feed as the dependent variable, then recovered it with an AR(1) prediction of the price of other goods. For the forecasts of the price of livestock, Berck and Chalfant used seven independent variables: the deflated price of feed lagged once and four periods, per capita consumption of livestock lagged one, two, and four periods, lagged real per capita income, and the lagged price of other goods. They did not deflate the price of livestock.

Bessler used a Bayesian vector autoregression (BVAR) which included all seven series in the data set. The series for price of other goods, income, and population were included in differenced form. The BVAR was determined by Bessler to be a fourth-order model with some time variation to the parameters. The coefficients all had prior means of zero; the nondifferenced series had priors of random walks, while the differenced series had priors of zero. The parameters that control the strength of the priors were set as follows: overall tightness = .6, cross-equation tightness = .4, decay = 1.0, and time variation = .01.

Criddle and Havenner used a bivariate state space model of the two price series for their forecasts. The best model was characterized by three states and a lag parameter of six periods. Their state space model constructs the conditional state vector of the bivariate series from lagged values of the two price series and lagged errors in a form that is a minimal sufficient statistic for the two series. This state vector is then multiplied by a parameter matrix to obtain forecasts of the two series. For more details on all three of the methods, see the papers immediately preceding this one (Berck and Chalfant, Bessler, Criddle and Havenner).

The forecasts for the three models, along with the actual values of the two price series are shown in table 1. The actual values were constructed

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Table 1. Actuals and Forecasts

OBS	P1	P2	ACE1	ACE2	BVAR1	BVAR2	SS1	SS2
71	2.3351400	1.4725390	3.3837919	1.8233114	3.3007500	1.6365500	3.8314866	1.6194072
72	2.6536770	2.4951890	3.4061981	2.2448025	2.8382900	2.0909400	2.5527816	2.1613480
73	2.5330420	1.4606420	3.5038864	1.9147685	3.0363700	1.7496100	2.9431754	1.8186444
74	2.3031700	1.8339350	3.4398076	2.4108124	2.7167200	2.0763300	3.0841177	1.8882261
75	2.8612510	2.8044090	3.4622139	2.4156384	2.7760400	2.0208900	2.1880894	2.2289281
76	2.5405630	1.7152650	3.6085943	1.6802673	3.1398900	1.5100300	3.6608450	1.4178326
77	3.5651980	2.1699800	3.5028266	2.4840834	3.2500700	2.1902700	2.6079127	2.0776198
78	4.8709440	2.0198300	3.7502977	2.1970451	3.2924300	2.0033200	3.4573106	1.9573171
79	4.8630000	1.6999000	3.9568838	1.9888949	4.3053800	1.9796400	4.5904846	1.9862904
80	3.7671360	3.4471330	4.1065917	2.2387075	4.6803500	2.2909600	4.4023010	2.3237932
81	4.2778610	1.9454070	3.8862518	1.6836667	3.6501400	1.1317800	4.3167759	1.6224683
82	3.5239900	2.2285910	3.7439612	2.0004301	4.1959900	2.0183600	4.4880941	1.8571166
83	5.0037940	2.6686570	4.0192965	2.2952979	3.4351200	2.0174600	3.1920529	2.2761553
84	5.7615590	1.5562530	4.4004759	1.6641369	4.6742600	1.8581800	5.2590708	1.5908158
85	4.5201860	2.2913710	4.5429875	2.2686074	5.2282500	2.5090500	4.7417108	2.5106864
86	3.6168050	2.1737770	3.9611104	1.9680219	4.5730700	2.1299600	4.7559000	2.0396233
87	4.2979070	1.6405840	4.1094805	2.0156193	3.9343000	1.9226700	4.0406413	1.9649148
88	4.1010900	2.4001360	3.7955088	2.4358692	4.1293500	2.2912000	4.0237004	2.2334058
89	4.3284030	1.9195770	3.9006458	1.7674972	4.1847100	1.9373400	4.1740779	1.9808397
90	3.5856450	2.4360910	3.8417217	2.2383127	4.0612700	2.0775400	4.4052099	2.0051645
91	4.0184880	1.6699420	2.7871984	2.7291987	3.9106700	1.9866400	3.6223475	2.0558040
92	3.4180290	1.7731980	2.9693333	2.3115499	4.1307100	2.2138500	4.2798856	1.9486272
93	4.0243680	2.2351820	2.5016336	2.8044090	3.6671400	2.2522500	3.1643753	2.3465290
94	3.5281210	1.7124560	2.9719851	2.3660932	4.2572700	1.9109000	4.4075459	1.7729241
95	3.3023420	2.3439980	3.1377543	2.8044090	3.7791400	2.1372100	3.4238912	2.2351612
96	3.5530210	1.9458360	2.6507797	2.7294991	3.7723600	1.9297700	3.6636736	1.8680753
97	2.1920140	1.8741750	2.8087425	2.4046519	3.5215700	2.0016300	3.7002451	1.9669608
98	2.4536800	2.1122680	2.7036812	2.8044090	2.9229100	2.0353900	2.6495597	2.0430395
99	2.2116880	1.5593060	2.5112967	2.8044090	2.8813500	1.8064500	2.9342775	1.8119887
100	2.2130570	2.0586150	2.7336634	2.8044090	2.3891500	2.0817000	2.5407567	2.0256582

by the authors using the methods and equations described in McIntosh and Dorfman.

Evaluation of the Forecasts

As discussed in McIntosh and Dorfman's introductory paper, the participants were told in advance that their forecasts would be evaluated on the basis of mean-squared forecast error and on ability to predict turning points. Given this information, the participants are likely to have based their loss functions for the selection of their final models on these two criteria. As pointed out by Zellner, one must be careful to evaluate forecasts with a norm consistent with the loss function used to construct them. Therefore, the main statistics used for evaluating the performance of the forecasts will be the mean-squared forecast errors of the models and the values of the Henriksson-Merton test for value of information in a forecast series.

The Henriksson-Merton test has a null hypothesis that a forecast series contains no information. The test is based on the direction of revision of the series (i.e., whether the differences are positive or negative) and how often the forecasts correctly predict those revisions. The ability to predict the direction of revision of a series is considered by this test to be the definition of a forecast containing information. This makes sense for many financial series where the ability to predict the direction of change of a series is enough to make money (or decide on hedges, etc.). The result of the test is an exact, finite sample, confidence level for the rejection of the null hypothesis. For example, a given series of forecasts might lead the test to declare a 95% confidence level for that series' containing information. The higher the level of confidence, the more revisions the model correctly identified with its forecasts. For more details, see Henriksson and Merton.

Along with the mean-squared forecast errors (*MSFEs*) and the Henriksson-Merton confidence levels, the mean absolute percentage errors (*MAPEs*) were also calculated because they are a commonly reported statistic (table 2). The subtable for each statistic has three rows: the first for all thirty observations (71–100); the second

Table 2. Summary Statistics of the Forecasts

ACE1[a]	ACE2	BVAR1	BVAR2	SS1	SS2	MOD1	MOD2
Mean-Squared Forecasts Errors							
0.57028[b]	0.29753	0.52330	0.14521	0.66968	0.10394	0.51673	0.08623
0.55592[c]	0.15348	0.58887	0.19476	0.73541	0.14131	0.62016	0.11264
0.59902[d]	0.58562	0.39216	0.04609	0.53824	0.02919	0.30987	0.03343
Mean Absolute Percentage Errors							
0.19237[b]	0.22586	0.17772	0.12972	0.20675	0.11173	0.17049	0.10369
0.18698[c]	0.14154	0.17073	0.14797	0.20391	0.12950	0.17406	0.11691
0.20314[d]	0.39449	0.19170	0.09323	0.21243	0.07619	0.16336	0.07725
Confidence Levels from the Henriksson-Merton Tests							
0.96452[b]	0.99965	0.79376	1.00000	0.55002	1.00000	0.99085	1.00000
0.96511[c]	0.99994	0.65754	0.99994	0.53501	0.99994	0.96511	0.99999
0.66667[d]	0.50000	0.66667	0.97619	0.33333	0.97619	0.83333	0.97619

[a] ACE1 is the ACE model for $p1$, the price of feed, ACE2 is the model for $p2$, the price of livestock. Similarly BVAR1 and BVAR2 are the forecasts of $p1$ and $p2$ from the BVAR model, SS1 and SS2 are the forecasts of the state space model, and MOD1 and MOD2 are the forecasts from the OLS estimation of the true model.
[b] This row is for observations 71–100.
[c] This row is for observations 71–90.
[d] This row is for observations 91–100.

for the first twenty (71–90), which the participants could see; and the third row for the last ten observations (91–100), which were truly out of sample. For comparison, the statistics for the "true model" used to generate the data are included in the table. This true model is the OLS estimation of the correct functional forms for the demand and supply models shown in McIntosh and Dorfman. The only current period right-hand-side variables in the price-dependent demand functions are the current period quantities. For these variables, the predicted values from the quantity-dependent supply equations were used (the supply equations had only lagged right-hand-side variables).[1] OLS estimates are consistent and efficient because the system of equations is recursive and because the errors used in generating the data set were independently distributed normal random variables.

Several general conclusions can be drawn from table 2. For the price of feed, the BVAR model seems generally to have outperformed the other models in terms of accuracy (*MSFE* and *MAPE*). For ability to predict turning points, the ACE model had the highest confidence levels for the price of feed. For the price of livestock, the state space model performed the best in terms of the accuracy-measuring norms (*MSFE* and *MAPE*). The results of the Henriksson-Merton tests showed that the BVAR and state space models had identical confidence levels for the ability to predict turning points. In a number of instances, the forecasts from the three models beat the performance of the true model in terms of accuracy. The ACE and BVAR models each had a smaller *MSFE* for the price of feed than did the true model over the first twenty observations (71–90), and the state space model had a smaller *MSFE* than the true model over the last ten observations (91–100) for the price of "livestock." The state space and BVAR models also beat the true model once each in terms of *MAPE* and tied it twice each in the Henriksson-Merton test results. The ACE model also tied the true model once in the Henriksson-Merton test.

To draw a clearer picture of the relative performances of the different models, a loss function combining qualitative and quantitative measures was developed. Assume that a decision maker must select a single model for use in forecasting each of the series. Further, assume that the decision maker desires a small *MSFE* and the ability to predict the direction of revision. A particular loss function that such a decision maker could use is

$$(1) \qquad L = \alpha MSFE + (1 - \alpha)(1 - c),$$

[1] While it might be possible to construct a better instrument for the quantities than the predictions from the supply equations, these instruments were used so that the true model's forecasts were completely based on structural equations. Although a better instrument for the quantities likely would have improved the true model's performance, the construction of the true model's forecasts was for comparison purposes only and not an attempt to produce the best forecasts possible.

where c is the confidence level from the Henriksson-Merton test. This loss function simply takes a convex combination of the *MSFE* and the significance level from the Henriksson-Merton test of the forecasts. The significance level is used in place of the confidence level so that a low value is a "good" instead of a "bad" result. The loss function in (1) was evaluated for each participant's forecasts of each price series for three subsets of the data: all thirty observations (71–100), the first twenty (71–90), and the last ten (91–100), and for values of α ranging from 0 to 1 (the loss was computed at intervals of 0.01 over this range).

The results of the loss computations for each model allow the models to be compared by a single scalar-valued norm. For the price of feed, the ACE model dominated completely over the first twenty observations (71–90), having the smallest loss for all values of α. Similarly, the BVAR model had the smallest loss over the last ten observations (91–100) for all values of α. Over all thirty observations (71–100), the ACE model had the smallest loss for $\alpha \in [0, .78]$, while the BVAR model had the smallest loss over the remaining range, $\alpha \in [.79, 1]$. The state space model never had the smallest loss for the price of feed. However, for the price of livestock, the state space model completely dominated in terms of minimum loss. The state space model had the smallest loss for all values of α over all three subsets of the data. Because of equal values for the Henriksson-Merton test confidence levels, the ACE model tied the loss function value of the state space model at $\alpha = 0$ over the first twenty observations and the BVAR model tied with the state space model at $\alpha = 0$ over both the entire thirty observations and the final ten observations. Other than these ties at an extreme point of the range, the state space model had the smallest loss for all values of α because of smaller *MSFE*s than the other two models over all three subsets of the data and equal or greater confidence levels for the ability to predict direction of revision. This dominance was interesting in light of the fact that the state space model failed to have the smallest loss for any value of α for the price of feed.

Another point to be made about the loss function concerns the loss connected with a pair of models not included in the competition. A pair of univariate ARMA models for the two prices were estimated. The univariate model for the price of feed, an ARMA(2, 0), proved to have the smallest loss for all values of α for the last ten observations and for all thirty observations. For the first twenty observations, the ACE model still had the smallest loss for all values of α. For the price of livestock, the univariate model, an ARMA(5, 0), also had the smallest loss everywhere except for the subset of the last ten observations and values of α from 0.51 to 1.0. The state space model still had the smallest loss for this subset over this range of loss functions. This performance by the univariate models suggests that the techniques used by the participants failed to noticeably improve the performance of their forecasts beyond forecasts from standard Box-Jenkins methods.

Diagnostics

For further insight into the performance of the various forecasts, several additional diagnostic tests were run. First, a test for unbiasedness of the forecasts was conducted; then, a Granger-Newbold test for significant differences in *MSFE*s was performed. The unbiasedness tests will be discussed first.

To test the hypothesis that the forecasts of a given model are unbiased a simple F-test from a least squares linear regression was used. The regression

$$p_t = \beta_o + \beta_1 f_t + e_t \tag{2}$$

was estimated for each price (p) and corresponding set of forecasts (f). The null hypothesis for the F-test was simply the joint restriction that $\beta_o = 0$ and $\beta_1 = 1$. The ACE model for the price of livestock proved to be biased when tested for all thirty observations—the test statistic was $F = 9.351$ compared to a critical value of 4.155 for a 5% significance level; but none of the other models had test statistics greater than 2.0. Thus, except for the ACE model's forecasts for the price of livestock, the forecasts all are statistically unbiased.

The results of the Granger-Newbold tests for significant differences in the *MSFE*s between a pair of models were more interesting. This asymptotic test utilizes only the forecast errors from each of the two models being tested. It creates two variables, $ep_t = e1_t + e2_t$ and $em_t = e1_t - e2_t$, where $e1$ and $e2$ are the forecast errors from the two models being tested. If the correlation coefficient between ep and em is significantly different from zero, then the model with the smaller *MSFE* has a significantly smaller *MSFE* at whatever significance level is used. The asymptotic variance of the correlation coeffi-

cient under the null hypothesis of equal *MSFE*s is $(1/T)$, where T is the sample size and a simple one-tailed t-test is appropriate (one-tailed because it is the absolute value of the correlation coefficient that is important; which *MSFE* is smaller is obvious).

The test was performed on all possible pairs of forecasts including the forecasts from the true model. Using a 5% significance level, ten of the pairs of *MSFE*s proved to be statistically different in size. For the price of feed, only two pairs of *MSFE*s were significant: both the BVAR and true model had significantly smaller *MSFE*s than the state space model over the last ten observations. For the price of livestock, however, many pairs of *MSFE*s proved to be significantly different in size.

Over all thirty observations the ACE model had a significantly larger *MSFE* than all three other models, and the BVAR model had a significantly larger *MSFE* than both the state space and true models. Over the first twenty observations, the BVAR model again had a significantly larger *MSFE* for the price of livestock than either the state space or the true model. Over the final ten observations of the price of livestock the ACE model's *MSFE* was significantly larger than the true model. The state space model was the only model to have a significantly larger *MSFE* for the price of feed (in two cases) and the only model not to have a significantly larger *MSFE* for the price of livestock. The estimated correlation coefficients for the tests and the critical values are shown in table 3.

Table 3. Results of *MSFE* Difference Tests

	Price of Feed			Price of Livestock		
	BVAR	SS	MOD	BVAR	SS	MOD
Correlation Coefficient for Observations 71–100						
ACE	.079	−.084	.063	.405*[a]	.613*	.663*
BVAR		−.274	−.046		.418*	.535*
SS			.241			.194
Correlation Coefficient for Observations 71–90						
ACE	−.054	−.194	.082	−.130	.237	.341
BVAR		−.233	−.092		.421*	.565*
SS			.179			.186
Correlation Coefficient for Observations 91–100						
ACE	.543	.128	.551	.252	.495	.622*
BVAR		−.807	−.151		.341	.501
SS			.640*			.347

[a] Asterisk indicates significant at the .05 level.

Conclusions and Overview

The results of this forecasting competition cannot be generalized in order to make sweeping claims about which methods work better than others given a criterion to evaluate forecast performance. The participants forecast only one set of data from one model. Even to make strong conclusions for one model would necessitate multiple draws from the data-generating process. However, while caution is in order, several conclusions can be drawn from this competition. First, no single method dominated the others; each proved superior for a series and a given set of loss functions. More important, the three models were not dominated by the true model. All three forecasting methods produced results that were relatively comparable to the known, true model. This suggests that structural econometrics may not be superior to time-series techniques even when the structural modelers are given the elusive true model. This, in turn, calls into question the use of large structural models for forecasting purposes when the true models are clearly unknown. Ultimately, the choice of the "best" forecasting model will remain problem specific and tailored to the particular loss function of the decision maker employing the forecasts.

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Policy Reform and Economic Development (Ann Krueger, Duke University, presiding)

Policies for Economic Development

Stanley Fischer and Vinod Thomas

At the end of a decade in which many developing countries have seen economic regress rather than progress and in which the formerly socialist economies for the most part turned away from central planning toward a market-oriented approach, there appears to be more agreement on the policies needed to produce growth and economic development than at any time in the post-World War II period. It remains to be seen whether the moment is more than fleeting. But it is certainty a good time to attempt to set out a mainstream, pragmatic view of what those policies are and of the uncertainties that surround the basic market- and outward-oriented approach to development.

In this paper we summarize the consensus views of the major economic policies needed to generate economic growth and development, consider issues that cut across these policy areas, and then provide brief concluding comments.

Consensus Views in Major Policy Areas

Policies conducive to economic development in three broad areas are an appropriate macroeconomic framework, the right set of sectoral policies and investments, and integration of the domestic economy into the world economy.

Getting the Macroeconomic Framework Right

Economic development is unlikely to occur unless policies produce a stable macroeconomic environment in which inflation remains reasonably low, the real exchange rate is competitive and stable, and foreign exchange and debt crises are avoided.

Fiscal policy. Tax rate and expenditure policies of government, including the composition of government spending, are the government's major microeconomic tools for affecting the allocation of resources. Beyond these microeconomic effects, fiscal policy is increasingly seen as the key to successful macroeconomic policy because, in its macro impacts, it has direct effects on the current allocation of resources, and because all methods of financing budget deficits have potentially adverse macroeconomic consequences when used to excess.

Given private saving, fiscal deficits displace private domestic investment or cause current account deficits. Thus, unless private saving responds fully to public sector deficits—and there is little reason to think it does—reduction of the fiscal deficit is likely to improve the current account and, perhaps after a period of adjustment, increase investment.

Fiscal deficits can be financed by printing money, by running down foreign exchange reserves, and by borrowing, at home or abroad. Each of these methods of financing can be used on a small scale (and in the case of running down foreign exchange reserves, on a transitory basis), but each is likely to have seriously adverse consequences if used on a major scale. Printing (high-powered) money is inflationary; running down foreign exchange reserves leads to a foreign exchange crisis; domestic borrowing can lead to higher real interest rates and an unstable domestic fiscal situation; and excessive foreign borrowing can lead to an external debt crisis.

While the conclusion is that fiscal moderation is the key to macroeconomic stability, this does not mean a zero deficit is optimal: a country that is growing fast can afford to run a larger deficit than one that is growing slowly; a country with a higher saving rate can run a given deficit for longer than a country with a lower saving rate. Fiscal moderation must be judged by the projected path of the debt (the sum of internal and external debt) to GNP ratio, and of the inflation rate and external balance. On the whole, inadequate fiscal policies remain a central factor be-

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hind the macroeconomic instability and poor performance of many developing countries.

The exchange rate. The second key to a sound macro framework is the exchange rate; it plays two roles in economic policy. First, the level of the real exchange rate is crucial to the development of the domestic economy: it establishes market incentives to export and the level of protection for domestic industries. Second, stability of the nominal exchange rate is one potential monetary anchor and a powerful anti-inflationary factor. When an economy operates with a fixed nominal exchange rate, the quantity of money becomes endogenous. This simplifies the job of the monetary authority; but, as experience shows, it frequently leads to a host of foreign exchange controls.

The two roles of the exchange rate sometimes clash: governments afraid of inflation hold the nominal exchange rate constant or devalue it too slowly, with the result that the domestic currency appreciates, and—with a lag—the current account goes into crisis. When the monetary anchor and trade incentive roles of the exchange rate conflict, the monetary anchor should be pulled up first and attention turned to the underlying source of inflationary pressure, typically the budget. Intermediate steps, such as a crawling peg, in conjunction with appropriate fiscal policy can provide some monetary stability without tending to produce an overvalued currency.

Investment, saving, and growth. Investment and saving ratios in rapidly growing economies are typically higher than those in stagnating economies. It is further clear that sustained growth will not resume in Sub-Saharan Africa and Latin America until investment ratios there rise significantly. The rise in the real interest rate in the 1980s reduces the possibilities of financing investment from abroad; economic growth in the 1990s will have to be largely domestically financed. The surest way to increase domestic saving is to increase government saving, i.e., to reduce the government budget deficit. The emphasis in the 1980s was on the importance of positive real interest rates for development. The emphasis is appropriate when the real interest rate is significantly negative, as it frequently is in high inflation economies: negative real interest rates appear to reduce saving and impair the efficiency of the financial system by reducing the share of saving that is intermediated through financial institutions. But once the real interest rate is positive, or nearly so, there is little empirical or theoretical reason to believe that further increases will increase saving.

Responding to shocks. Emphasis on the stability of the macroeconomic framework should not obscure the importance of the ability of the government to adjust macroeconomic policy quickly to external and internal shocks. Fiscal and monetary policy, and the exchange rate, may have to change rapidly when external conditions change; the more successful governments recognize change and respond to it. The need for flexibility is especially great for economies whose external earnings fluctuate a great deal, typically because they are dependent on earnings from one or a few primary commodities.

Sectoral Policies: Projects and Beyond

Macroeconomic policies for stability and growth usually need to be underpinned by appropriate sectoral policies to obtain a satisfactory supply response. Sectoral policies include investment decisions, pricing and regulatory policies, and institutional development.

Investments in agriculture, industry, infrastructure, and human resources have long formed the core of development efforts. The traditional approach was to pursue development projects in these sectors with the aid of project analysis of benefits and costs. The effectiveness of the investments, however, depends on the policy environment affecting the sector and the degree of institutional development.

Sectoral priorities and investments. Although there is no universal prescription for sectoral priorities for development, development usually requires increases in agricultural productivity permitting an increasing share of the labor force to contribute to industrial production. Accordingly, development is usually accompanied by an increasing share of industry in output. Human resource development is both an independent goal of development and an essential in-

strument of economic progress.

Unprecedented rates of population growth in the post-World War II period have contributed to low or negative per capita income growth in much of Africa, Asia, and for some time in China and India. Despite significant political opposition within the United States, international agencies have sought to assist governments to reduce population growth. Success to date has been limited, but there have recently been encouraging signs from some African countries, where population growth rates appear to be turning down as a result of government educational programs and the provision of contraceptives. Reducing the rate of population growth remains a priority of development policy in many developing countries.

Sectoral policies and strategy. The emphasis on the centrality of sectoral and macroeconomic policies to the success of projects has strengthened in recent years, along with the recognition that policies are of independent importance to sectoral performance. Measures to bring domestic relative prices closer to international levels and to establish a relatively neutral macroeconomic framework are often essential to enhancing sectoral performance. In agriculture, for example, incentives were historically suppressed by agricultural taxes. Perhaps more important, macroeconomic policies resulting in overvalued exchange rates have translated into heavy (often unintended) taxation of that sector. Adjustment programs in the 1980s have therefore focussed on both macroeconomic policies (exchange rate, import protection) and sectoral pricing policies (eliminating price controls on agricultural output, for example). Concurrently, many programs have also attempted to reduce the rather ineffective input subsidies in agriculture while improving the delivery of inputs and services.

The consensus is converging to the view that macroeconomic and sectoral pricing and regulatory policies should be relatively neutral, that governments should move away from interventions designed to favor particular industries, regions, or factors of production. However, moving toward neutrality may require active transitional government policies, for instance in restructuring public enterprises or the financial system (see also the next section). It also remains true that an active government investment program in the sectors, especially, physical infrastructure and human resource development and technology, is essential to development.

Integrating with the World Economy

The most successful performers of recent decades have been the newly industrializing economies, characterized by their relative openness and links with the world economy. To maintain these links, they have had to remain competitive in a rapidly changing world environment. Common to successful competition strategies is the reduction or elimination of discrimination against tradables—permitting exports and efficient import substitutes to be produced on a similar footing with nontradables.

However, such neutrality in the trade regime has been approached through different routes. Some successful reformers have substantially liberalized their trade restrictions (Chile, Mexico), others have intervened to offset existing biases against exports (Korea, Taiwan), and still others have done both (Indonesia, Turkey). Government controls have been especially prevalent in the area of capital flows in many countries. Interventions to encourage new technologies and to industrialize have also paid off on occasion.

Commercial policy reform. Developing countries are more open, and their trade regimes are more efficient than a decade ago. They have substantially reformed their exchange rate and export policies. They also have increased the efficiency of their import regimes by switching from quantitative restrictions to tariffs. But reductions in the levels of nominal and effective protection have been more limited than is generally believed.

Most countries that have implemented trade policy reforms have won long-term economic gains. The policy changes and additional financing under adjustment programs have both been associated with moderate improvements in output and export growth. However, supply response to changes in relative prices associated with the trade reforms has been limited in many countries. The main constraints on the supply response have been restrictive domestic regulations and inefficient public enterprise policies; growing protectionism in industrial countries; doubts about the permanence of the reforms; and inadequate institutions, infrastructure, entrepre-

neurial, and managerial capacity in the reforming country.

Issues Spanning Policy Areas

There are several issues that span policy areas. These include sustainable development, both country-specific and global environmental sustainability, and social, political, and economic sustainability of adjustment programs. Other issues include poverty alleviation, the balance between both public and private sectors, the World Bank's role, and adjustment lending.

Sustainable Development

Two issues fall under this heading. The first is environmental sustainability, which has both a country-specific and global aspects. One fear is that in many countries development is taking place by exploiting and destroying much of the resource base, and that such development is accordingly not sustainable. The presumption is that two-way links exist between growth and the environment: certain growth policies are consistent with environmental protection, and environmental care in turn contributes to sustained growth. But knowledge of the tradeoffs between measured growth and environmental protection must increase. At the same time, simple steps to prevent environmental damage, such as environmental assessments for all projects, are already being implemented.

Global environmental issues pose more difficult problems. If global warming is taking place, it is largely the result of current and past economic activities of the now-industrialized countries. If measures are put in place to reduce global environmental damage, the issue of burden sharing between developing and industrialized countries—as well as among all countries—will pose major political difficulties.

A second sustainability issue is whether the adjustment programs of many countries are socially, politically, and economically sustainable. Adjustment is more likely to be socially sustainable if the poor are protected during the process of adjustment. Political sustainability may depend on how adjustment affects the segment of population with political clout. In general, adjustment is more likely to be sustainable the sooner it shows economic results. One reason to provide external financing during the adjustment process is temporarily to reduce the extent of cuts in expenditures and in imports that would otherwise have been necessary.

Poverty Alleviation

Although the purpose of economic development is to reduce poverty, poverty alleviation is a separate goal of policy in developing as well as industrialized economies. Specific policies, such as targeted food subsidy and health programs, can be used to protect the poor and reduce poverty, even during adjustment. Bolivia's experiment with the Emergency Social Fund and Ghana's Program of Actions to Mitigate the Social Cost of Adjustment are examples. These are temporary measures (three years in Bolivia and two in Ghana). More fundamentally, education and other social programs can be designed to reduce poverty, even though in many countries social spending helps mainly the middle and upper classes. More effective and better targeted public expenditures are needed. Sometimes it would help to correct mis-targeting of existing public social expenditures, for example, by reducing public funding of education and curative health care expenditures.

The Balance between Public and Private Sectors

The new consensus on development policy places greater stress than before on the central role of markets, and on the private sector (in some countries, the informal private sector) as the engine of growth. The role of the public sector is seen as the creation of a favorable enabling environment for economic activity. The enabling environment consists of the legal, institutional, and policy framework within which economic agents operate.

A government that creates a favorable enabling environment has a large role to play, for instance in ensuring the provision of infrastructure, including social services, such as poverty alleviation, basic education, and access to health care; public security; a stable macroeconomic framework; and an efficient fiscal and regulatory system.

The most difficult question about the role of the government is whether it should take an active part in promoting particular industries, that is, whether it should pursue an industrial policy. Some successful elements of an active policy are clear: export development and assistance in

marketing, information, technology, and know-how. Expanding manufactured exports requires sustained efforts on both macroeconomic and microeconomic levels. Japan, Korea, and Taiwan have paid attention to the many nonprice requirements of export development. For a period of time, they also pursued export development while maintaining a certain degree of import protection.

The World Bank's Role

Since the start of its operations in 1946, the World Bank has moved from assisting in the reconstruction of post-World War II Europe to the development of basic physical infrastructure in the developing world, to financing developmental projects, and to the support of structural reform through adjustment lending. This evolution largely reflects a shift in the economics of development. A professional view that focussed on "critical mass" and the role of the economic planner has shifted, under the weight of four decades of experience, to a view that centers on establishing an enabling policy environment, the efficient decentralization of information, operation of incentives, and integration with the world economy.

This view also has become more realistic with respect to the goals and operations of governments. It has moved away from the simple notion of government as an altruistic entity and at the same time has accepted that significant changes cannot be instituted if they are not owned by the policy makers and administrators.

For the three decades from 1950 to 1980, the World Bank's almost exclusive role was to provide financing and technical assistance in the development of investments. Even since the advent of adjustment lending in 1980, about 75% of World Bank lending has continued to be for projects.

Adjustment Lending

The shift of World Bank operations toward adjustment lending in the 1980s has been associated with the debt crisis and its associated external shocks, the decline in general balance-of-payments lending to developing countries by the commercial banks. As the debt crisis developed, it became clear that the adjustments many of the indebted countries would have to make to the sharp reduction in external financing could be smoothed by the provision of rapidly disbursing loans by the World Bank. But to ensure that such loans were used to make economic adjustments to changed circumstances, the loan conditionality was tied to policy changes in the borrowing country.

Adjustment lending, as it has taken place in the 1980s, can be characterized as rapidly disbursing and policy based. However, these characteristics are separable, and slowly disbursing policy lending is possible.

Analytically, the shift to adjustment lending coincided with the recognition that the overall quality of economic policy management is key to economic development, and with the realization that a good economic environment is essential to project development. While early structural adjustment loans focussed on general macroeconomic reforms, the adjustment experience of the last decade has led to greater emphasis on sector-oriented programs, and thus to sectoral adjustment loans. These adjustment loans typically support significant policy changes in a particular sector or sectors, with disbursement depending on both the sectoral policy measures and the maintenance of an appropriate macroeconomic framework. The design of policy lending programs has been a subject of controversy for borrowing members, international organizations, and World Bank staff and management alike. Borrowers under the pressure of debt service requirements and domestic resistance protested at the hardships coincident with undertaking such programs. Some observers in donor countries also objected to the social burdens associated with the implementation on program conditionality, while others argued that adjustment loans enabled borrowers to avoid implementing required policy changes.

This controversy has tended to die down as some countries have shown success in pursuing adjustment policies, as nonadjusting countries have descended into economic disorder, and as the lack of alternatives to adjustment has become clearer.

Outstanding Issues

General agreement on the policies needed to produce growth and economic development will remain only if the currently agreed upon policies produce growth and development. Seen in that light, the challenges, particularly from Africa and Latin America, and most recently from the reforming socialist economies, are formi-

dable. In many cases, the problems are analytic, for instance, how to sequence the adjustment of a heavily distorted economy with macroeconomic and external imbalances to the market-oriented structure that its policy makers seek. In other cases, the problems are political: countries with infrastructure and analytic capacity lack the political ability to implement changes that are generally recognized to be desirable. This is not a problem only for developing countries. In other countries, inadequate human capital and institutional framework constrain development. It is essential to recognize that the problems of development differ from country to country, and that each country's policies have to fit its own structure while still recognizing the realities of the world economy in which it operates.

There are also deep questions about the role of external funding and the international development agencies. It is often argued that countries would have done better if left to their own devices and forced to confront their budget constraints earlier and harder. One can agree with this judgment for some countries, but not for most. Nonetheless, it is essential to recognize that an important goal of development is for countries to reach the stage at which they manage their own affairs.

Adjustment Policies and Economic Development

Jacob A. Frenkel and Mohsin S. Khan

The principal objective of the International Monetary Fund (IMF), as defined by its articles of agreement, is the correction of balance of payments disequilibrium in member countries. The policies the IMF recommends to reduce the degree and duration of external and internal imbalances that give rise to balance-of-payments difficulties must, however, be set within the context of achieving and maintaining price stability and satisfactory rates of economic growth.

In analyzing IMF policies designed to achieve these multiple objectives, it is useful first to consider the circumstances in which the IMF is called upon to assist in designing an adjustment program and in providing temporary financial support for it. The need for a stabilization program, whether supported by the IMF or otherwise, arises when a country experiences a persisting imbalance between aggregate domestic demand (absorption) and aggregate supply, which is reflected in a worsening of its external payments position. As long as foreign financing is available, the relative expansion of domestic demand can be sustained for an extended period, although at the cost of a widening deficit in the current account of the balance of payments, a loss of international reserves, rising inflation, worsening international competitiveness, and a heavier foreign debt burden. However, this situation cannot last indefinitely. Eventually, the country would lose international creditworthiness, and the cessation of foreign credits would necessitate adjustment. This forced adjustment may be very disruptive for the economy. The aim of the IMF under these circumstances is to provide for an orderly adjustment, and the first task is to stabilize the economy—lower the rate of inflation, restore international competitiveness, reduce the current account deficit, and check the loss of international reserves—by correcting the macroeconomic imbalances that led to these problems. Once macroeconomic stability is assured, then policies to expand the productive capacity of the economy and improve the efficiency with which resources are utilized are more likely to be successful. Experience and theory both suggest that, to achieve adjustment with growth, such a pattern of sequencing of macroeconomic and structural policies is warranted.

Although growth is a central element in the IMF's objectives, it should be stressed that the IMF is not a development agency. Its mandate is to provide temporary financial support and not development aid. Consequently, the IMF does not possess a "development paradigm" as such. Nevertheless, by establishing macroeconomic equilibrium in the economy, the IMF sets the necessary foundation on which development is based. Furthermore, the IMF has increasingly emphasized structural reforms in its policy advice. While this change stems from the recognition that economic stability cannot be regained without basic institutional and economic change, such reforms have a direct bearing on long-term growth and the structural transformations that make up the development process.

This paper outlines in broad terms the policy content of IMF-supported adjustment programs designed to achieve macroeconomic stability and higher growth. The description of policies, including aggregate demand policies (principally monetary and fiscal), structural policies, exchange rate policies, and external debt policies, is taken up in the next section. The empirical relationship between macroeconomic stability and long-run growth in a sample of 101 developing countries over the period 1973–88 is then examined. The concluding section draws some lessons on the role of IMF policies in economic development.

IMF Economic Policies

To achieve balance-of-payments viability, price stability, and a sustained satisfactory rate of economic growth, the IMF helps countries de-

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sign a fairly comprehensive package of economic policies (IMF 1987). The specific policy measures differ across countries, but each package has certain common features. The most important characteristic of the IMF policy package is perhaps the emphasis placed on the role of the market and relative prices in the expansion and allocation of resources. For this reason, measures to reduce distortions created by price rigidities, monopolies, and imperfect competition, taxes, subsidies, trade restrictions, and other direct controls over different facets of economic activity are generally given prominence in IMF-supported adjustment programs. Experience has shown that the decentralization of economic decisions and the use of realistic prices to guide such decisions can improve the efficiency of production and investment in a variety of political and institutional settings (including centrally planned economies. See Wolf).

However, this emphasis on "getting prices right" is not to suggest that the IMF sees no role for the government in the economy or that it is opposed to any and all forms of government intervention. The standard economic case for government intervention, i.e., when there is evidence of obvious market failure, is well appreciated, as are the arguments that developing-country governments need to provide the basic infrastructure for development to take place. The general market orientation has implications for the type of development strategy that is adopted, but this is not why the IMF advocates the policies it does. Indeed, the IMF is neutral on development strategies, and its policies are geared primarily to achieving the best possible macroeconomic outcomes under given circumstances. (For a discussion of alternative development strategies, see Sen.)

What then are the policies that would be considered to achieve balance-of-payments viability in the context of low inflation and improved growth performance? In general, most economists would tend to subscribe to the following set of measures typically included in IMF-supported adjustment programs:

(*a*) *Monetary restraint* aimed at reducing the growth of absorption and the rate of inflation. Generally speaking, a fall in the supply of credit will lower absorption directly through wealth effects and, by pushing up interest rates, cause the interest-sensitive components of aggregate demand to decline. The reduction in aggregate demand would tend to improve the current account of the balance of payments and put downward pressure on inflation (Frenkel and Johnson; Frenkel and Mussa; and IMF 1977, 1987). However, in curtailing monetary and credit expansion, care must be taken to prevent crowding the private sector out of the credit markets, so that government borrowing from the banking system, including the central bank, frequently must be restricted.

(*b*) *Interest rate policies* are employed to set rates at positive real levels, but not so high as to choke off investment and possibly cause the collapse of financial institutions. Thus, in general there is a consensus that real interest rates should be positive but low.

(*c*) *Reduction in the fiscal deficit* through cuts in government expenditures and/or increases in taxes. Theory and substantial empirical evidence can be used to support the proposition that a reduction in the fiscal deficit tends to reduce aggregate demand. *Ceteris paribus,* this improves the balance of payments and reduces inflationary pressures in the economy. Furthermore, because developing-country governments rely heavily on bank financing of fiscal deficits, an improvement in the budgetary position reduces the amount of liquidity being injected into the system. For both these reasons—reducing the claim on resources in the economy and restricting monetary expansion—cutting the fiscal deficit becomes an essential, if not the most critical, element of an adjustment program. However, in choosing the method for reducing the deficit, the relationship between public and private saving and public and private investment also must be considered. For example, under some circumstances, an increase in public saving may lead to a partially offsetting fall in private saving.[1] Also, private and public investment may be complementary to the extent that the public sector provides the necessary infrastructure; thus, reductions in public investment may have adverse effects on private investment and growth (Blejer and Khan).

(*d*) *Exchange-rate action* to ensure a real exchange rate that would improve international competitiveness and create the incentive to expand the production of internationally tradable goods. The main theoretical aspects of devaluation are well known (e.g., Dornbusch), but determining the appropriate change in the nominal exchange rate to achieve a target real exchange rate as well as predicting the effects of

[1] For a theoretical discussion of this issue, see Barro, Frenkel and Razin (1987, 1988). Empirical tests of the relationship between public and private savings in developing countries are contained in Haque and Montiel.

the policy are not easy tasks. Without a comprehensive general equilibrium model to specify relevant relationships among the exchange rate, trade and capital flows, and inflation, short-cut methods based on considerable judgments must be used. For example, it is common in developing countries to employ variants of purchasing power parity (PPP) calculations to assess the extent of the overvaluation of the domestic currency. It is assumed that a particular real exchange rate was "right" at some base period; and, using this as a target, nominal exchange-rate action and supporting policies (monetary, fiscal, incomes) to attain it are employed. This approach is susceptible to error and should be used with appropriate caution. By and large, the limited empirical evidence available supports the hypothesis that devaluation will work in the direction of improving competitiveness and the balance of payments. While it is sometimes argued that devaluation leads to a recession, there are doubts about the generality of this proposition (Lizondo and Montiel).

(*e*) Policies to *reduce external debt* if it is perceived as currently unsustainable or to limit foreign borrowing if it is likely to become unsustainable in the future. To assist countries in a debt crisis situation, the IMF has undertaken a number of steps: providing additional financing from its own resources, facilitating rescheduling of the existing stock of debt, encouraging additional lending to the country from both official and private sources, and participating in market-based debt reduction schemes.[2] All of these efforts are made with the idea that the country eventually will return to normal borrowing relations. In general, external-debt policies in IMF-supported programs are aimed at easing the liquidity problems of countries facing a debt problem and helping them maintain their long-run growth path.

(*f*) Introducing *structural reforms,* i.e., financial sector reforms, producer pricing policies, trade liberalization, tax reforms, etc., to make the economy more flexible and efficient. Such structural reforms can help in the adjustment process by expanding productive capacity of the economy. Nevertheless, structural reforms are not without difficulties. First, by their very nature, distortions tend to be microeconomic, and microeconomic policy measures suffer from certain theoretical weaknesses. Very soon one runs up against the propositions of the theory of the second best, and it is not always clear whether removing only some distortions will produce an increase in efficiency and welfare in the economy overall. Second, the issue of time lags is very relevant to the IMF as a short-term lender.[3] Substantial time may be needed for structural policies to show positive benefits, and adequate foreign financing is usually essential in the interim to ensure that the adjustment is as costless as possible. Finally, there is the sequencing of reforms. Unfortunately, economic theory provides little guidance on the optimal sequence, and it is difficult to generalize from country-specific experiences. What does emerge from experience is that domestic goods and labor markets should be liberalized prior to trade liberalization. Similarly, it has been argued that the liberalization of the trade account of the balance of payments should precede that of the capital account because asset markets adjust more rapidly than goods markets. The opposite sequence could result in large capital movements that could adversely affect the real exchange rate and domestic monetary conditions (Frenkel 1982, 1987; Khan and Zahler). Sound theoretical and empirical reasons also suggest that macroeconomic stabilization should generally precede large-scale domestic financial sector liberalization to prevent interest rates from overshooting (Villanueva and Mirakhor). Other than these broad lessons, little more can be deduced; accordingly, one needs to proceed on a case-by-case basis with the pace and sequencing of structural reforms.

Empirical Aspects of IMF Economic Policies

The next question is the extent to which IMF policies achieve their objectives of an improvement in external and internal balance—that is, macroeconomic stability—and whether macroeconomic stability is associated with higher long-term growth.

Starting with the first part of this question, consider the recent evidence in Khan for a sample of sixty-nine countries that had upper credit tranche arrangements with the IMF during 1973–88. Khan shows that on average the implementation of an IMF-supported program led to (*a*)

[2] The theoretical and empirical aspects of the debt crisis are addressed by the papers in Frenkel, Dooley, and Wickham.

[3] The new Structural Adjustment Facility (SAF) and the Enhanced Structural Adjustment Facility (ESAF) that provide financing to low-income countries have significantly lengthened the maturity period.

an improvement in the overall balance of payments, (*b*) an improvement in the current account balance, and (*c*) a reduction in the rate of inflation. But as is almost always the case with stabilization efforts, this improvement in the external position and in the inflation picture is achieved with some short-term cost, namely a decline in the growth of real gross domestic product (GDP).[4] Over time, however, this cost is reduced, and the positive effects of programs are strengthened. Thus, the empirical evidence confirms the hypothesis that the adoption of an IMF-supported adjustment program generally will lead to a more stable macroeconomic situation.

Establishing that IMF programs are conducive to macroeconomic stability is not the end of the story; the link between macroeconomic stability and long-run growth and development also must be shown. Linking macroeconomic stability to long-run growth is not easy. The economics profession lacks a fully satisfactory theory that directly relates macroeconomic policies and structural reforms to growth, other than through changes in the rate of capital formation. Therefore, macroeconomic policies are judged by their effects on investment, under the argument that policies with a favorable effect on investment are good for growth. But growth involves many factors other than physical investment. In general, growth of output will depend, *inter alia,* on growth of the labor force, changes in the efficiency of investment, changes in human capital (education, skills, and health), and technological developments.[5] It is not known as yet how precisely economic policies of the type contained in IMF programs will affect these other determinants.[6] There is presumption, supported by limited empirical evidence, that policies to achieve macroeconomic stability will affect growth in a positive fashion because they create a climate which is conducive to investment, increased domestic savings, and a larger flow of foreign financing, all of which will tend to raise the growth rate (Fischer, Dornbusch and Reynoso). Beyond these generalities, relatively little is known.

In the absence of a suitable theory to test, we conducted a purely statistical analysis of the relationship between long-run growth and macroeconomic stability. To this end, simple regressions were run relating the growth of real GDP to various indicators of macroeconomic stability using cross-section data for 101 developing countries averaged over the period 1973–88. These indicators were chosen arbitrarily because there is no generally accepted measure of macroeconomic stability. The following alternatives were included: inflation, the variance of inflation, the fiscal balance (as a percentage of GDP), the percentage change in the real exchange rate, and the variance of the real exchange rate.

The results of these alternative regressions are shown in table 1.[7] These equations are not intended to explain growth; they should be interpreted only as simple tests of association. As such, one should not be overly concerned with the general lack of goodness-of-fit one observes in the estimated equations. With regard to the relationships themselves, there is uniform support for the hypothesis that growth and alternative measures of macroeconomic stability are positively related in this large sample of developing countries. The countries with higher average growth rates over the period 1973–88 also tended to have lower average rates of inflation,[8] lower variance of inflation rates, better average fiscal positions, larger average depreciations of the real effective exchange rate, and lower variance of real effective exchange rates.

Taken at face value, the regressions confirm the view that countries that have adopted appropriate policies aimed at keeping the inflation rate low, not allowing overvaluation of the currency, and maintaining fiscal responsibility, and, furthermore, making these policies predictable, have also managed to attain higher long-run growth rates. One could, therefore, argue that to the extent that IMF policies establish macroeconomic equilibrium in the economy, they play a positive role in the growth and development process.

Conclusions

This paper has shown that the IMF recommends a variety of policies to attain balance of viabil-

[4] This result is consistent with other empirical evidence; see the survey by Khan and Knight.

[5] See, for example, Fischer for a recent discussion of the factors that are important in the determination of growth.

[6] Available empirical evidence indicates that these factors could account for more than 50% of the changes in growth rates in developing countries.

[7] The data for these tests are obtained from IMF, *International Financial Statistics*, and the *World Economic Outlook* database.

[8] A similar negative relationship between growth and inflation is obtained by Dornbusch and Reynoso.

Table 1. Cross-Section Estimates of Growth and Macroeconomic Stability Relationships

Equation	Constant	Inflation	Variance of Inflation[a]	Fiscal Balance[b]	Real Exchange Rate[c]	Variance of Real Exchange Rate[a]	R^2 (s.e.)
(1)	3.644	−0.004					0.04
	(13.40)	(1.92)					(2.59)
(2)	3.556		−0.001				0.03
	(13.45)		(1.51)				(2.61)
(3)	3.955			0.088			0.06
	(12.25)			(2.41)			(2.56)
(4)	3.525				−0.111		0.04
	(13.68)				(2.11)		(2.58)
(5)	4.052					−2.481	0.06
	(11.78)					(2.48)	(2.56)

Note: All data are averages for the period 1973–88; the dependent variable is the average growth of real GDP; t-values are given in parentheses.
[a] As measured by the coefficient of variation.
[b] As percentage of GDP.
[c] Percentage change in the real effective exchange rate. The exchange rate is defined as units of foreign currency per unit of domestic currency.

ity, price stability, and the development of the productive resources in its member countries. Eliminating internal or external imbalances can in principle be accomplished by a range of policy packages; some of these packages stimulate economic growth, and some do not. The IMF recognizes that strong and long-lasting adjustment is feasible only if the economy is expanding; thus, it is committed to favoring those policies that enhance the growth rate. To the IMF, the establishment of a stable macroeconomic environment is a *sine qua non* for increased savings, investment, and foreign inflows, all of which are central to the growth process. The empirical tests described in this paper provide some support for this view.

The main lesson that emerges from experience, as well as from the analysis in this paper, can be summarized as follows: without macroeconomic stability, economic growth can falter and not be sustained. Furthermore, without broad-based economic growth, the basic structural and social transformations which comprise the process of development will not occur, and the other objectives of development policy (such as a more equitable distribution of resources and income, providing employment, improving living standards and the quality of life, and the alleviation of poverty) are unlikely to be met. This does not mean that adequate growth will automatically follow if countries achieve macroeconomic stability. But the chances are greatly improved. In this sense, IMF policies can be thought of as improving these chances and, thus, the basic conditions for economic development.

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A New Paradigm for Policy Reform and Economic Development

Gordon C. Rausser

Throughout much of the world, significant institutional changes are in the air, wind, and water. Evidence is accumulating that democracy has won the political battle and that markets have won the economic battle. Some serious scholars have even argued that the history of thought about first principles, including those governing political and social organizations, has come to an end (Fukuyama). For those who hold this view, Hegel was simply too early in forecasting the end of the evolution of thought about such first principles nearly two centuries ago. The entire Marxian experiment was nothing more than a 150-year detour which corroborated Hegel's view that the "end of history" coincided with the emergence of liberal-democratic states following the French and American revolutions.

Regardless of whether the history of ideology is over, a new consensus on economic, political, and civil freedoms has emerged. This consensus means more than simply adjusting macroeconomic policy, achieving stability, and selling off a few government-owned enterprises in an attempt to set developing countries on a path toward broad-based economic growth. Instead, it means creating a vision of an open economy underpinned by an open polity; identifying and removing the obstacles to economic participation, obstacles that lock the ordinary citizen out of the game; enhancing the availability and utility of information resources by shaping incentives and helping to establish the basic rules of social transactions; encouraging more efficient organization of economic activity whether by market, hierarchy, or hybrid modes (Williamson) in ways that may lead to fundamental restructuring of an economy; and fostering institutional frameworks that expand the role of human choice and promote the full panoply of entrepreneurial energies.

In developing countries, the above consensus emerges from the empirical evidence, not through the tunnel vision of some theoretical constructs. In operationalizing this experience, a number of economic "lessons" must be kept in mind. The lessons are drawn from developing countries which differ not only in the details of their economic policies but also in their whole approach to growth and development. These differences have lasted not just a year or two but, in some cases, for decades. As a result, one of the major crosses our profession must bear, namely, that we cannot conduct controlled experiments, has been largely removed. Although the post-World War II experience is admittedly an imperfect substitute for controlled experiments, it does reveal that in economic development the facts speak loudly about the links between actions and consequences.

Serious inspection of postwar economic development suggests that (*a*) "getting the prices right" or "setting the property rights straight," or both, is not sufficient if an economy is to reach its full potential; (*b*) bad governments and institutions have been a serious, if not the most serious, obstacle to economic development in less-developed countries (LDCs); and (*c*) all public sectors pursue a mix of predatory and productive activities—bad governments emphasizing the former and good governments finding a way of promoting the latter. As Krueger (p. 19) has recently noted, successful developers have governments which "have been active in providing infrastructures—communication, transport, power, education, agricultural research, and extension—in support of economic growth. But, in almost all of the countries in which intervention, controls, and parastatal activities have been far reaching, these infrastructure investments have been sadly neglected." In terms of nuts and bolts, de Soto has shown that government regulations create serious roadblocks to economic participation. In many instances, cleverly disguised

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regulatory roadblocks provided significant deterrence to entry.[1] North has observed that, in much of the developing world, because governments play such an immense role in economic allocations and choices, the integration of political and economic theory is essential.

The Role of AID

In the above setting, what is the role or business of the Agency for International Development (AID)? As suggested in a recent report on the mandate of AID, a long list of concerns has engaged the agency's personnel and resources: humanitarian, political, national security, poverty alleviation, equity, economic growth, etc. (U.S. Agency for International Development). Evidence is provided that, increasingly, the role of the U.S. foreign aid program is limited either to smaller, strategically less significant countries or to playing the part of disbursement agent in strategically important countries. (For an analysis supporting this view, see Rausser 1989.)

In the face of the conflicting objectives for AID, there is some hope that this agency of the U.S. government, in fact, may be able to reduce strategic considerations in its outlay decisions over the next few decades. The signals justify the hope that economic growth-oriented development will no longer take a back seat to other U.S. objectives are fundamental. First, as noted earlier, ideological differences will be far less important over these next few decades than they have been since World War II. Moreover, if Hegel's view is correct, it is only a matter of time before liberal-democratic first principles are accepted by all LDCs. Second, the world itself has changed, both with the United States playing a relatively less dominant role on the world economic stage and with the potential for a new rapproachment with the Soviet Union. With these changes may come less concern about strategic alliances with developing countries.

It is to be hoped that the eideological battle that has existed in many LDCs over much of the post-World War II period is close to an end. However, regardless of how the trade-offs between economic and geopolitical or military goals unfold as the world role of the United States changes, AID should be able to focus more easily on providing support for achieving self-sustaining economic growth and development. In reviewing the potential effectiveness of AID's programs in promoting sustainable economic growth, a few conclusions are inescapable: (*a*) policies that encourage competitive forces are key to attaining sustainable economic growth; (*b*) institutions play a crucial role in creating and maintaining growth-oriented policies, whether defining and improving the security of property rights, lowering the costs of transactions (organization, supervision, coordination, monitoring, metering, etc.), or enhancing enforcement through an improved judicial system; and (*c*) policies and programs supported by international development agencies often place heavy emphasis on prescriptions from macroeconomic paradigms and fail to consider institutional bottlenecks and political constraints to implementing these prescriptions.

Given the expertise and charters of the World Bank and the International Monetary Fund and the comparative advantage of other bilateral donors, the niche where AID can be the most effective may be in the development of new institutions, institutional change, and the political economy of policy reform. These activities are labor intensive and require long-term commitments. The "mission infrastructure" of AID is well suited to perform the needed tasks. At the core of these tasks is a serious investigation of constitutional economics in each country.

The basic questions that pertain to such analysis are of the following types: Is the constitutional order of the country conducive to free inquiry and social experimentation or is it fundamentally repressive? Does the constitutional order provide ease of entry into the economic system, the political system, and ease with which the legal foundations of new institutions can be established? Does the constitutional order provide sufficient self-correcting mechanisms to limit excessive predatory governmental behavior? Does the constitutional order motivate agreement on basic values and processes for conflict resolution—a sense of civil order—to reduce the cost or risk of innovation?

Along with such fundamental constitutional issues, the basic political economic questions that must be analyzed include: What are the constraints and obstacles to economic growth that directly result from the power of interest groups? Who wins and who loses from current or reformed policies? What is the sustainability of

[1] To demonstrate this problem, de Soto tried to open a clothing business in Peru, legally and without paying bribes along the way. It took a lawyer and 3 other people a total of 300 days, or 1,200 man days, to complete all the necessary forms and to obtain all the signatures that were needed to start a business. As a comparison, de Soto performed the same task in Florida. Here, it took only 3 hours to start a new business. Peru is not unique.

the institutions and policies that support the status quo? What are the economic policy reforms that will promote economic efficiency and counter the constraints and obstacles that currently exist? What mechanisms or approaches can be utilized to obtain political consensus for the implementation of the proposed reforms? Does compensation make sense for those groups that are harmed by the adjustments that emerge after the policy reforms are implemented? With the implementation of growth-promoting policy reforms, are there public goods that might be offered to improve social services (e.g., health, population, education, etc.) that would ease the pain of adjustment resulting from the policy reforms? How can the interests of those groups which will benefit from reforms be appropriately articulated and channeled? What institutional changes are required for the reform policies to be sustainable? Do these institutional changes effectively alter the level and distribution of political power within the country?[2]

Alternative Paradigms

Over the years, a number of paradigms have been advanced for economic development (Bardhan). But very few, if any, paradigms exist which structure internally consistent analytical frameworks for policy reform. For the determination of government policy, two extreme perspectives within the economics profession have emerged over the years. The first is the public choice perspective, which focuses on the allocation of public resources in the political market, emphasizing redistribution to powerful interest groups (Downs, Buchanan and Tullock, Olsen, Becker). This literature quite naturally has led to analysis of rent-seeking and directly unproductive activities (Tullock, Bhagwati) which generate predatory behavior or "government failure." In this paradigm, interest groups play the role of the proverbial 800-pound gorilla—they go where they want, they sit where they want, and they take what they want. In essence, this paradigm is limited by its profoundly cynical view of the political process.

The predatory government perspective may, in fact, be an overreaction to the harm done by the paradigm at the other end of the spectrum (namely, the conventional welfare economics framework), where the state is a benign instrument for serving the public interest. As Stiglitz has emphasized, market failures abound in LDCs, and it would indeed be fortuitous if a benign instrument such as government intervention could be found for solving these pervasive failures. The market failures emanate from a number of different sources: unclear and insecure property rights, significant externalities, imperfect competition, informational imperfections, myopia, irreversibilities, sufficient need for and maldistribution of public and mixed goods, etc. Considerable empirical evidence supports a deeply skeptical view about the existence of a benign state to solve such problems anywhere in the world.

The conventional welfare economics paradigm presumes that "first-best outcomes" are achievable. The poor performance of many third world countries argues against the achievability of first-best outcomes. Neoclassical economic theory, on which the conventional welfare economics paradigm is based, cannot account for such performance. Moreover, as North (p. 32) notes, this theory "simply assumes away all the relevant issues."

Throughout the developing world, the public sector is not the perfect benign instrument envisaged by conventional welfare economics. But neither is it the manifestation of powerful interest groups concerned only with their well-being. In the conventional welfare economics paradigm, all political power resides in the hands of a benign government that attempts to correct whatever market failures might exist. In the new political economy paradigm, all political power resides with interest groups, and whatever actions are taken by the public sector can be characterized as predatory. Both of these paradigms represent extremes on a continuum. Either of them will make incorrect inferences of how policy outcomes are generated and thus should not be used in isolation to assess and evaluate reforms.

Governments do more than either engage in the improvement of allocative efficiency through collective action or simply serve rent seekers and the politically powerful. Accordingly, an alter-

[2] In this discussion, the implied dichotomy or separation between institutional change and the political economy of reform is made for convenience only. These two components of the development process are not separable. Bad policies will, over time, fundamentally corrupt and distort institutional performance. As most would agree, by initializing the movement to more innovative and competitive economies, policy reform and structural adjustment are essential to the process of institutional change in economic development. As the work of Ruttan and his associates has shown empirically on numerous occasions, market signals can induce institutional change. To the extent that these signals are severely distorted through predatory government behavior, institutional change can be expected to be misdirected.

native paradigm is needed that recognizes that power is distributed between the various interest groups and government and that maldistribution of power can blunt any and all efforts at economic policy reform. Moreover, this paradigm must recognize that governments can have some separate autonomy and can seek "leadership surplus" (Froelich, Oppenheimer, and Young).[3] What is needed is an internally consistent framework which admits the possibility and necessity of accommodating various interests. An appropriate political economic model is needed to conceptualize the bargains, pacts, compromises, and efforts that are undertaken to shape policies acceptable not only to those that have the greatest capacity to obstruct the process but also to others who stand to benefit from the policies.

Effective governments pursue productive activities while engaging in predatory pursuits for political-economic reasons. Specifically, predatory policies can compensate those groups and individuals that have sufficient political power to limit or obstruct efficient policies which lower transaction costs in the private sector. What is needed is an integrated framework that recognizes the joint determination of both predatory and productive governmental interventions. This framework must admit the political economy perspective of public choice theorists (all predatory, no productive activities) and the conventional welfare economics perspective (all productive, no predatory activities) as two special cases. In this new paradigm, institutions play a central role.

Variations in transaction costs and political power and influence mean that it must be possible to customize the new paradigm for the culture and customs of each country. In the proposed paradigm, current policies are viewed as a rational outcome of a political economic process. This political-economic process is one where the public sector can be viewed as a "central coordinator." A hierarchy structures the relationships between the authoritative center and the subordinate peripheral participants. The decision agents constituting the center are not oblivious to their own material well-being, social status, political power, etc. As a result, the center in this organizational setting is exposed to attempts by various interest groups to exert influence. In this framework, it has been shown, using a game-theoretic formulation (Zusman and Rausser), that if all power does not reside at the "center" and participants are in a position to reward or penalize the leadership, organizational failures naturally arise.

To illustrate this proposition, consider the classic case of regulatory organizations that attempt to manage the "tragedy of the commons" problem. Our results show that, while the center may fully internalize the common group interest, various self-interested participants who are accordingly narrowly rational in their attempts to influence can generate an organizational equilibrium that is suboptimal. Nevertheless, the establishment of this regulatory body will lead to a result that is superior to the pure predatory outcome but worse than the purely productive outcome. In essence, to the extent that the decision center internalizes at least part of the overall social interest, collective action improves upon the market-determined solution.

In this paradigm, good governments realize that their actions result in burden and gain sharing which may be unequally dispersed, that political power is unequal, and that because of limited information it is not possible to identify a priori the creative innovators or sectors that will prove to be the engines of growth from those that will not. Good governments also recognize the critical importance of "credibility." Would food riots have occurred in Egypt or bus fare and energy price riots in Venezuela if either of those two governments had had credibility? Did the South Korean government have more or less credibility when AID was actively involved in the structuring of that country's economic policies? A similar question may be asked today of Honduras and Egypt. Recent advances in game theory applications have shown the importance of the role of precommitments to government credibility. Properly designed precommitments for which it is impossible to reverse course have been shown to lead to intertemporal policy consistency. Credibility of commitments is indeed crucial to the implementation of significant reforms.

In the context of public policy reform, the mixed productivity/predatory paradigm offers a number of insights and refutable implications. Review of the history of major reforms in public policy throughout the world, whether developed or developing, shows that reform is motivated

[3] In the Froelich, Oppenheimer, and Young framework, leaders compete with other potential leaders for ascendancy and, once in office, maximize their surplus or profit by providing collective goods against taxes, donations, or purchases promised in the election process.

by one or more of the following events or forces: a major change (usually a precipitous deterioration) in the economic environment, a creative new design in implementation of policy mixes and/or compensation schemes, and/or the emergence of new political factions or major institutional changes.

A major change in the economic environment (e.g., the first 1980s oil crisis in Indonesia; the 1986–89 economic crisis in Poland, the Soviet Union, and East Germany; and the 1985 hyperinflation in Bolivia) shifts the possibility frontiers and leads to new mixes of productive and predatory policies. The design and implementation of new policy mixes and compensation schemes can alter the obstructionist behavior of various interest groups and their resultant deadweight cost in any rational collection of policies. South Korea's public policies are a wonderful illustrative example. The design and implementation of compensation schemes in Canada in response to the free-trade agreement with the United States is also illustrative. Developing better compensation schemes may be thought of as finding improved means to negotiate the allocation of society's welfare. In the search for reforms that augment the total size of a country's economic pie, predatory compensation schemes may be necessary. One of the political economic costs of implementing growth-promoting reform policies may be that associated predatory compensations must be made available to obstructionist interest groups.

Finally, major organizational and institutional changes can cover the full gamut: law and order, property law and property rights, contract law, laws governing exchange, the provision of public goods, conflict of interest, etc. At the core of any sustainable policy reform is the underlying constitutional framework. Changes in the relative benefits and costs of organizing those who would benefit are also major means of generating sustained reforms. Increasing the responsiveness of beneficiary groups to changes in their welfare allows the public sector to move in the direction of less wasteful combinations of productive and predatory policies.

Unless the "governing" criterion function that rationalizes the mix of predatory and productive policies is changed, unsustainable alterations in policy should not be termed "reforms" at all (Rausser 1982, Rausser and Foster, this issue). To move from a current mix of policies to sustainable reforms entails the movement from one policy equilibrium to another. This movement can be sustained through the emergence of new hierarchies and markets. In fact, one major market is the market for reform itself.[4]

Concluding Remarks

Throughout the developing world, the integration of political and economic forces is essential in understanding and prescribing roles for the public sector in order to achieve economic reform. Critical to this integration is an appreciation of the microforces within organizations and the central role played by transaction costs in any paradigm designed to explain current policy or prescribe policy reform. In the economics profession, there is a growing appreciation of these basic propositions. To the extent that public policies lower transaction costs in the private sector, collective behavior of the government pursues productive political economic interventions, expanding the size of the country's economic pie. To the extent that public policies serve powerful interest groups through predatory political economic schemes, portions of the country's economic pie are reallocated with varying degrees of waste. What has not been recognized in previous paradigms but is formally admitted by the paradigm suggested here is that these types of policies go hand in hand; frequently, predatory policies are offered as compensation to those that are harmed as a result of implementation of productive policies. Hence, predatory behavior becomes one of the political economic costs that must be borne when implementing growth-promoting policies, especially those that reform existing policies in effect to serve influential interest groups.

The integrated productive and predatory framework outlined in this paper not only offers an explanatory hypothesis for differing political economic equilibriums but also provides the basis for operational prescription. This prescription facilitates the search for a more equitable solution to public problems, the search for basic consensus on the nature of the public interest, and the creation of public trust based on a shared

[4] It should be kept in mind that the demand for reform can be realized most easily through constitutional-democratic processes which can reward or penalize officials or governments for the overall performance of their economic policies. The Hobson's-choice alternative is authoritarianism which, although it can sustain good economic policies by turning a deaf ear to protests, can also repress the demand for reform. The latter outcome is by far the most frequent among authoritarian governments.

sense of legitimate authority. The framework explicitly recognizes the task for public policy economists emphasized by Aaron in his Richard T. Ely lecture at last year's AEA meetings (p. 13), "to identify policy rules that are robust and are important not only economically but, in a fundamental sense, politically."

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Policy Reform and Economic Development: Discussion

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My comments deal with the subject matter discussed in the papers and not with the actual performance of the agencies in question. I will comment only on two major issues, the role of knowledge and on the mapping of the effects of macro policy onto the growth process. This is intended to supplement the discussion in the papers, which I found to be insightful and recommend for reading.

Why, with all the knowledge with respect to macro policy projected by the papers, do countries get into deep problems? Also, and not independently, will countries which have restored stabilization remain stable or, alternatively, will macro crises recur? The following discussion accepts the position presented in the papers, that our knowledge of stabilization has increased. Thus, if it is only knowledge that matters, then we should expect a much better performance in the future than in the past. What is the scope for such improvement?

Trying to answer these questions requires broadening the framework to include the political economy aspects of the problem. Following Rausser, a distinction is made between benevolent and predatory governments. A benevolent government is one that plays the role of the social planner, whereas a predator exploits the system. Why should they have different policies? After all, a predator that plans to stay in power should also be interested in a strong economy because such an economy offers more opportunities for exploitation. Thus, a government need not be benevolent in its motives in order to have an interest in the well being of the economy. On the other hand, a government need not be predatory in order to damage the economy. To discuss this point, the question of political survival must be considered.

To extend the discussion, we sketch the behavior of governments within a framework of rational choice. We begin with the social planner and ignore motives of income distribution. By assumption, the social planner aims at maximizing the expected discounted value of the stream of utilities derived from per capital private consumption, c_t, $E\Sigma\beta^t u(c_t)$, where β is the discount factor, determined by the consumers, and E is the expectation operator. The maximization is subject to the resource constraint of the economy, which is not spelled out here, nor do we spell out the instruments used to affect the choice of c_t. For this objective to be fulfilled, the first-order conditions require that at each t, $u'(c_t) = \beta E u'(c_{t+1})$. This condition does not identify the government in power because it is immaterial.

The social planner is an altruist benevolent. At the other extreme, we can think of a government which (a) wants to stay in power and (b) extracts resources for noneconomic activities. Its utility depends on c_t as well as on the size of its operation, $g_t(i)$, and the transfers, $s_t(i)$, where i identifies the government. Its behavior is determined by choosing a time path for (c_t, $g_t(i)$, $s_t(i)$) so as to maximize $E\Sigma\beta^t(i)u[c_t, g_t(i), s_t(i)]$. The government has a subjective probability distribution of survival which depends on $[c_t, g_t(i), s_t(i)]$, and its discount factor is not necessarily identical to that of the social planner. The political benevolent is an intermediate case which avoids extracting rent for himself but uses g and s as instruments to enhance its probability of staying in power. Populism can be included in this case. The predator will try both to exploit the system and to stay in power. What comes out of this exercise is that the less secure he is about his political survival, the more he will exploit the system today by increasing $s_t(i)$ at the cost of weakening the economy, even though it is in his interest to have a strong economy. Recent events have shown that such transfers are quite robust to a large subset of ideologies. This implies that they may persist in an ideology-free era as well.

The purpose of this comment is to indicate that we can expect to have a wide range of modes of government behavior, depending on the util-

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ity function and the prevailing political and economic environments. We have analyzed government behavior within a micro framework, but the government is not just another agent in the economy which, by the law of large numbers, has practically no influence on the economy. A government which deviates considerably from the policy of the social planner often spells disaster.

The question is whether our ability to evaluate the consequences has a positive effect on the policy change. Judging from other areas of human behavior, such as consumption of drugs, my guess is that knowledge helps but by itself cannot eliminate deviations from the policy of the social planner. From all this it becomes clear that problems of stabilization are not likely to become obsolete.

We turn now to the second topic: from stabilization to growth. There are three important signals which are affected by macro policies and which affect growth: The real rate of exchange, the real rate of interest, and stability. The real rate of exchange affects sectoral incentives according to the sectoral degree of tradability. For instance, agriculture is more tradable than nonagriculture and therefore is more susceptible to deterioration of the real exchange rate. The rate of interest affects sectors according to their capital intensity, measured by the capital share. Finally, instability increases risk.

To evaluate the consequences of these signals, we can think of an agent who wants to maximize the present value of the expected returns to his operation, or more generally the expected utility, subject to the constraints which are in part private and in part public, such as infrastructure and the institutional set up. All three variables mentioned above enter into the framework and as such affect the decisions on resource utilization. Aggregating over individuals, we obtain sectoral behavior, which can be further aggregated to obtain the behavior of the economy. The pertinent constraints are determined by the level of aggregation. Note, however, that when the economy is open, it competes with the rest of the world for resources, and therefore the domestic profitability affects the rate of domestic resource accumulation.

An increase in per capita output is obtained by increasing capital and physical and human input per unit of labor, the participation rate in the labor force, and by technical change. Technical change is strongly associated with capital accumulation. A distinction is made between the available technology and the implemented technology. Low-income countries do not use the same techniques that are used by the rich countries because they lack the resources to do so. Thus, the implementation of the available technology depends on available resources. Consequently, through this chain of events, improving domestic incentives encourages capital accumulation and therefore growth. This conceptual framework translates itself to empirical analysis which can quantify the effect of macro policies on growth. A recent study (Mundlak, Cavallo, and Domenach) of economic growth in Argentina during 1913–84 shows that such effects are substantial.

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Mundlak, Yair, Domingo Cavallo, and Roberto Domenach. *Agriculture and Economic Growth in Argentina, 1913–84*. Washington DC: International Food Policy Research Institute Res. Rep. No. 76, 1989.

Policy Reform and Economic Development: Discussion

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Donor and other agencies/institutions more indirectly involved in development assistance are increasingly emphasizing policy reform as a prescription for economic growth. For coordinating assistance programs and for the developing nations which must ultimately deal with these agencies simultaneously, it is important to understand the associated policy reform paradigm and the scope of the policy activity. Thus, this session is especially timely. And the authors have provided thoughtful reviews on policy reform approaches and the empirical information on possible impacts.

The discussion of the papers has three themes: policy space, operating paradigms, and indicators of success. Most attention is given to policy space because the major point of the discussion concerns an associated problem of institutional design.

The policy space for the International Monetary Fund (IMF) is identified by concerns about external and internal imbalances and stabilization. However, the interests in the timing of policy change and intermediate term economic growth appear to be leading the IMF into the domestic policy arena and economic development. World Bank programs have focused on equitable economic growth among sectors and nations. Major policy instruments have been loans for sector and infrastructure development. But problems with loan repayment and debt servicing have led the bank to become more involved in macroeconomic and fiscal policy.

The U.S. Agency for International Development (USAID) has had an apparent divided attitude toward policy intervention. Significant politically motivated development assistance moves through USAID. Alternatively, the USAID budget, not constrained by political interests, has primarily supported technology and adoption, infrastructure development, food assistance, and other instruments argued (albeit weakly) to be benign relative to developing country policy. However, with the emphasis on private sector development, USAID has directly attempted to impose policy reform. And, with the "November Report" and related developments, the broad nature of this evolving sense of the policy space is becoming more clear.

The problem indicated by this cursory assessment of the policy space is the significant overlap. This overlap implies major problems for targeting development assistance efforts and, to say the least, for the developing nations "benefitting" from multiagency policy interventions. Is an overlap in the policy space a sign of institutional failure? Should policy reform initiatives be better coordinated? How could such coordination occur? And, should attention be given to redefining or even combining the agencies?

The second theme is operating economic development policy paradigms of the agencies/institutions. For the IMF, the operating paradigm is orthodox macroeconomic and financial policy. To the extent that the IMF is involved in domestic development, the policy approach appears to have standard microfoundations. The World Bank also uses a policy framework that is within the confines of modern economic theory, concentrating on sector development and intersectoral relationships. And, to the extent that the Bank has been drawn into macroeconomic and international policy, the policy approach appears to be standard. For USAID, the apparent evolving paradigm is anything but orthodox. This operating paradigm extends beyond neoclassical policy economics to directly address questions of institutions and the political economy of nations.

Perhaps this broadening has been stimulated by frustrations with a USAID policy reform paradigm that is more limited in scope. If the paradigm cannot reveal why the policy that is to be changed evolved in the first place, how can it guide approaches to reform? It is likely that for

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the IMF, World Bank, and other institutions more involved in economic development a broader policy paradigm will emerge as a result of this and associated policy change questions.

The third theme is indicators of success. Without a clear operating paradigm, it is difficult to develop consistent performance measures. The performance measures indicated by the IMF and World Bank suggest that the orthodox policy paradigm implicit in their approaches is being stretched by the indicators. For example, among the indicators identified by the IMF were a restricted role for government, more reliance on markets, and higher economic growth. For the World Bank, the performance indicators included improved income distribution, private sector involvement, and other aspects of institutional reform. USAID has perhaps a less well-defined set of performance indicators but a broader implied development policy paradigm. Whereas the indicators advanced by the World Bank and the IMF suggest an expanding paradigm, those of USAID suggest further refining of the broader policy paradigm for economic development.

The papers suggest emerging questions on the organization of the institutions directly and indirectly supporting economic growth of developing countries. Are the countries receiving consistent advice and direction in policy reform? To what extent do the recommended policy changes involve institutional and political issues beyond the scope of the operating paradigm? Does a broader development paradigm imply a rethinking of the organization current regulatory and assistance agencies?

Books Reviewed

Arrow, Kenneth J., ed. *The Balance between Industry and Agriculture in Economic Development.* Proceedings of the Eighth World Congress of the International Economic Association, Delhi, India, vol. 1, Basic Issues. New York: St. Martin's Press, 1988, xxii + 297 pp., $55.00.

This first of five volumes is divided into two parts: "Plenary Papers" and "The Historical Perspective." Part 1 includes eight invited addresses which discuss agriculture–industry relations from a variety of perspectives. Part 2 has four chapters on the treatment of the subject in economic thought and two on the experiences of Spain and Italy in rural industrialization.

Arrow's introduction focuses on the analytic usefulness of agriculture and industry as "opposed categories" in the analysis of economic growth. Rao's inaugural address casts grave doubts on the existence of systematic relations between sectoral proportions and economic development. He concludes that advances in technology rather than increases in industry's relative share of the gross national product (GNP) is the key to rapid economic growth. In his presidential address, Arrow traces how certain developments in neoclassical economic theory affected economic development theory justifying biases in favor of industry. Pointing at problem areas emerging from better empirical knowledge, he then highlights implications for development planning and policy. According to Schultz, modern economic growth spawns disequilibria that have agricultural connections. But prevention of disequilibria is not the real issue. It pertains to making economic agents equilibrate efficiently through human capital formation and the right kind of economic organizations as well as incentives.

Ishikawa examines the implications of the lateness in industrialization of Asian economies by focusing on two features of their agriculture: virtually intact village communities and customary economies. Sen draws lessons for Africa and India from each other's experiences in the prevention of famines and gender bias. Bogomolov discusses why agriculture exhibits less dynamism than industry and then outlines the institutional reforms underway in socialist economies to improve the balance between the two sectors. According to him, the question of an appropriate balance between the sectors, however, cannot be tackled in isolation from global realities of unequal economic development and the influence of the developed countries' policies on the world market conditions. Both Lakdawala and Singh examine the agriculture–industry relation in the context of India's capital-goods-oriented growth strategy and the policies followed to implement it within a democracy. Singh also questions a rigid adherence to standard postulates which emphasize the role of agriculture in economic growth, particularly in a global environment of increased possibilities for both import of capital and trade.

In Part 2, Roncaglia's main thesis is that "abstract concepts useful at a specific stage of history, for the analysis of specific issues, may lose validity over time owing to changes in the economy and in the relevant issues" (p. 157). He demonstrates this by discussing the conceptual prehistory of representing the economic system as a process centered on the dichotomy between agriculture and industry (i.e., "productive" and "sterile") sectors. Thus, this dichotomy may not always be appropriate to analyze the complex problems of development in the present day world. Presenting the essence of Quesnay's and Adam Smith's arguments, Eltis concludes that "twentieth century economies may therefore find that they are applying industry-boosting arguments which derive from propositions Smith established in conditions where Quesnay's reasoning is more appropriate" (p. 176).

Bharadwaj traces the agriculture–industry relation in the political economy framework of Quesnay, Adam Smith, Ricardo, and Marx with a focus on the generation, appropriation, distribution, and utilization of surplus. The theoretical distinction between agriculture and industry recedes in the neoclassical paradigm concerned with the relative-price-guided allocative efficiency of resources. But the political economy viewpoint and the agriculture–industry dichotomy have been revived in the analysis of developing economies. Pointing to the different kinds of exchange involvements of different classes of producers and the diverse exchange systems that get formed on the "market," Bharadwaj concludes that one of the main tasks of research is in constructing a framework that takes into account the institutional variations in production and exchange relations that influence and are influenced by the process of accumulation. Sachs also questions paradigms and theories used to analyze the complementarities and trade-offs between agriculture and industry within the context of "a commoditised economy" and the division of labor between countryside and city. Finally, Vasques-Barquero and Fua discuss historical experiences of Spain and Italy in the structural transformation of rural areas which minimized the destabilizing impact of industrialization on social order and agriculture.

Various contributions in this volume thus relate to three main questions. First, how useful is classification of the economy into agriculture and industry sectors in discussing economic growth? Second, which issues are pertinent and what are the complexities in them in discussing the balance between these two sectors in the context of growth in the contemporary developing world? Third, what are the implications of these questions for economic theory and also for

development planning and policy? Viewed from these angles, this volume is full of both sobering truths and thought-provoking insights.

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Bhagwati, Jagdish. *Protectionism*. Cambridge MA: MIT Press, 1988, xiii + 147 pp., $16.95.

If Bhagwati's book is any indication, the Ohlin lectures are bound to become an important part of the political economy literature on trade. Bhagwati initiated the Ohlin lecture series in 1987, and the book is drawn from those talks. The book offers something to all audiences—policy makers, undergraduates, and graduate students (who will find basic theoretical concepts put into an historical and political context). His aim is to describe the forces that influence current political thinking about trade policy. In the process he demonstrates that the welfare principles supporting free trade still hold up remarkably well, even in today's changing trade environment.

Bhagwati weaves several themes together in these lectures and covers a wide range of issues. A central theme is that trade policy is formed through the interplay of current ideology, political and economic interests, and institutional factors. For instance, to explain the role of ideology in policy formation, he considers the post-Depression, free-trade bias in the United States. This bias was nurtured by theoretical literature, which, in turn, was reinforced by real-world examples such as the economic losses suffered by the United States from the Smoot-Hawley beggar-thy-neighbor tariff policies. To show the role of political and economic interests in forming trade policy, Bhagwati cites how, in the era of the Cold War, liberal U.S. trade policies were seen as a way to enhance national security. Institutional factors such as the establishment of the GATT and the post-Smoot-Hawley shift in tariff-setting authority from Congress to the executive branch also contributed to a free-trade bias in the United States.

Analagously, Bhagwati describes the forces behind recent increases in protectionism, embodied in popular calls for reciprocity, "fair trade" or "level playing fields." He discusses the rise in non-tariff barriers, such as voluntary export restraints (VERs) and voluntary import expansions (VIEs)—a term he has coined to describe the protectionism he perceives in U.S. unilateral trade actions such as Section 301 and Super 301 cases. He notes the similarities in arguments for protection at both ends of the manufacturing spectrum: the traditional low-technology, low-wage goods such as textiles in which other countries have comparative cost advantages, as well as the high-wage, high-technology goods that are increasing under pressure from Japan and other East Asian countries. Bhagwati exposes the flaws in "fair trade" arguments and criticizes increasing political pressure for the United States to seek quantitative, "results-oriented" trade solutions, such as the U.S.–Japan semiconductor agreement, which may simply divert trade to the United States rather than opening up foreign markets. Bhagwati provides insights into and from recent theoretical, empirical, and topical literature, ranging from strategic trade theory to "manufacturing matters."

Another theme of the book, based on work with Douglas Irwin, is that the pattern of protectionist sentiment in the United States bears strong similarities to the British experience in the 19th century. For example, the arguments in favor of maintaining the Corn Laws are uncannily similar to today's popular arguments favoring fair trade over free trade.

The book is filled with morsels of information that will surprise many readers. For example, many will be surprised to learn that Japan exports less than 15% of its GNP, compared to over 20% in the United Kingdom, over 25% in Canada, and nearly 35% in South Korea. (The U.S. exports less than 10% of its GNP.) In addition, there is an excellent, if compact, bibliography on theoretical, empirical, historical, and institutional trade policy literature.

The book is also filled with humor that often teaches. My favorite is the description of the economists' reliance on counterfactual analysis: when an economist is asked how his wife is, he replies, "Compared to what?" (p. 56n). In another case, expressing optimism in the continued political viability of free trade, Bhagwati cites his faith in the "Dracula Effect: exposing evil to sunlight helps to destory it" (p. 85).

There are minor points to quibble with in these lectures. For example, the data are unnecessarily out of date, often stopping around 1980; some institutional terms are not defined, such as RTAA legislation; and some arguments could be tighter. Readers will probably gain more from the book if they are already familiar with trade literature and current trade policy matters such as the current GATT Uruguay Round of multilateral trade negotiations or the ongoing Super 301 trade actions legislated in the 1988 Trade Act. Even then, readers may find themselves looking up certain GATT articles cited to find out what they cover. But all in all, this is a fun, informative book that sends the clear message that the foundations of free trade are still sound.

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Boland, Lawrence A. *The Methodology of Economic Model Building: Methodology after Samuelson*. London: Routledge, 1989, x + 194 pp., $45.00.

If an interesting book is defined as one that at least occasionally stirs the emotions and even gets one riled, this book passes the test for me. At various times I was excited, bored, fascinated, confused, in admiration, and in disagreement. At times, for instance when dealing with shoulder logs, such as page 176, "hardly any mainstream economist will read anything more than [the title of a paper dealing with philos-

ophy of science] . . . no matter how well your paper is written, no major journal will waste its time or funds having it reviewed," I felt that I could understand why the author experienced fifty-five rejections (p. x) before his first article (on the identification problem and the validity of economic models) was published (by the *South African Journal of Economics*). Perhaps here too is a partial explanation of why in the bibliography (sic—a "bibliography" in which Fritz Machlup's book on *Methodology in the Social Sciences* doesn't rate a mention!), there are more citations to the works of mechanical engineer turned mathematical economist-cum-philosopher/methodologist Boland than there are to the works of Nobel laureates (who range from Einstein to Haavelmo).

Boland's central topic is how economists have applied Karl Popper's views of the need for falsifiable theories. He relates methodological debates about falsifiability and testability to wider debates on empiricism and the truth status of models in natural and social sciences. In doing so, he argues that the practice of model building in economics reflects more the methodological prescriptions of Paul Samuelson than the falsificationism attributed to Popper. Boland's eight substantive chapters are sandwiched between a scene-setting prologue and a confessional epilogue (titled as the book subtitle, to the likely chagrin of Samuelson).

Part I on "Applications of the Popper-Samuelson Demarcation" gets into some technical elaboration of the P-(for Popper) dimension in models.

Part II on "Popper-Samuelson Demarcation vs. the Truth Status of Models" has a wide-ranging review of the conventionalist controversy and, notwithstanding what Boland (p. 108) alludes to as "this somewhat tedious exposition," there are some fascinating insights. One analogy of particular novelty is the reincarnation of the Samuelson-Bator-et al., "social choice problem," of production possibilities curve through to the utility possibilities envelope (UPE) and the social welfare function (SWF) as the "paradigm choice problem" in which the final diagram has axes of simplicity and generality with a methodological possibilities function corresponding to the UPE and a verisimilitude function corresponding to the SWF. In an aside of interest to technological fundamentalists, Boland (pp. 113–14) notes relative to "failures" of welfare theory that "clearly, the more interesting (and pressing) problem is to find the means of expanding the various possibilities frontiers."

Part 3 is "Exploring the Limits of the Popper-Samuelson Demarcation" and features three provocatively titled chapters: 6, "Informative mathematical economic models"; 7, "On the impossibility of testability in modern economics"; and 8, "Model specifications, stochasticism and convincing tests in economics."

Chapter 8 was for me the best, harboring as it does both the high and low points for Boland's treatment. The high point (section 2.2) is the author's main vehicle for deriving operational procedures from his critique through the idea of testing with models of counterexamples (along with models of the theories under test) and thus arriving at one of four test results (namely, model inconsistency, corroboration, refutation, or ambiguity, p. 150). The low point is the following subsection 3: "Stochasticism and econometric models."

I found the hard line taken on stochasticity (of both reality and models), such as (p. 152), "there is always a serious danger of intellectual dishonesty in asserting that the environment is stochastic," to be totally unconvincing. I predict that many readers will part company at this point, especially if they have a considered investment in either econometrics or the economics of uncertainty and the quantification thereof. The issue reappears with aggression again in subsection 4.4: "The irrelevance of the probability approach," where he says (p. 164) that "So far, I have not said anything about probabilities. Many readers will find this irritating. . . ." Indeed, I did, for the just-noted reasons; but even the first sentence is not literally true, as back on page 115 reference was made to "maximizing expected (sic) probability." If my prediction above proves true, it would seem reasonable for Boland at some stage to reconsider the matter of environmental stochasticity and thus also whether (contrary to the publisher's cover blurb) the more-than-twenty-year research project is yet really complete.

Boland rightly says (p. 139) that "It is always very difficult to write about methodology." As one who has seen undergraduates' eyes glaze over at the -isms and -ologies that pervade the literature of the philosophy of what we aspire to do as scientific economists, I feel that Boland has done a reasonable job of expressing his arguments in language that students will welcome if not exactly relish. Perhaps the easy style can be illustrated through the following selections:

"Weakness [of axioms] has a lot to do with generality and universality . . ." (p. 27).

"Despite the lofty platitudes embodied in [the Popper-Socrates] philosophy, many economists may still see the worship of falsifiability as a misplaced desire for the hole instead of the donut!" (p. 84).

"Deciding which variables are to be included in a model, and deciding which of them are to be exogenous, are the most fundamental methodological decisions that a model builder must make" (p. 8).

"A stochastic model is one which systematically allows for the movements of the target . . . and follow[s] from a methodological decision *not* to attempt to explain anything completely" (p. 21).

"I have shown enough . . . to illustrate that some methodological decisions that model[ers] . . . might make for the convenience of their mathematical analysis can lead to extremely unfortunate methodological consequences whenever one also is concerned with the requirement of testability" (p. 79).

"The fact is that the economic theory used in econometric studies is usually very primitive" (p. 82).

The acceptance of [the neoclassical] paradigm [of 'liberal philosophy'] stops the potential infinite regress . . . and hopefully avoids the two problems of subjective truth—namely dishonesty and self-delusion" (p. 134).

At one of my low moments in my reading, I posed the question of whether Boland's book should enter the acquisition portfolio of the student of economic methodology who, as always, has a bounded budget. In particular, what if the bookshop stocks Samuelson's *Foundations* . . . and Popper's *Logic* . . . as well as Boland's. At that moment, I decided Samuelson's was a must and, if there was budget for only one more, Popper's should complement it. On reflection, perhaps this was too harsh and, at any rate, Popper's is sure to be in the library whereas Boland's may well not be. Certainly Boland's book will prove useful to instructors, and thus presumably also to serious students, in courses involving questions of method in economic research. For agricultural economists as a particular subset of "students of methodology," however, it is likely that they will derive more value per dollar invested from Glenn Johnson's (1986) book.

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Chan, Sucheng. *This Bittersweet Soil: The Chinese in California Agriculture, 1860–1910.* Berkeley: University of California Press, 1986, xxv + 503 pp., price unknown.

Chan addresses an important and relatively neglected facet of the history of California agriculture—the significant role played by the Chinese immigrants during the second half of nineteenth century and the early part of twentieth century. This is a remarkable piece of dedicated scholarship. In a major, original piece of research, the author tells the story of a people's courage, hardship, and successes in a lucid style. The book will force many of us, both experts and laymen, to revise our notions about many important events in American socioeconomic history, including the history of economic development of California, the history and politics of immigration in this country, the history of farmworkers, and the role of Chinese immigrants in America.

This effort is not entirely new; yet, thanks in large part to the accidental discovery of a set of previously unused data, the author is able to describe these events with a great deal of sophistication. This is the first part of a two-volume work. The second volume will investigate why the anti-Japanese movement focused on the Japanese farming population in California.

The author sets for herself the task of investigating several questions: Why did the Chinese immigrants come to America, and in particular to California? What obstacles did they face on their way and once they arrived here? Where and how long did they stay in California? What contribution did they make? Why did they succeed as long as they did? What prevented them from succeeding more than they did? When and why did they leave California agriculture? What if they had stayed longer? All of these are subsumed under the overarching theme: What historical role did the Chinese immigrants play in the agricultural development of California in the years 1860–1910?

The book includes eleven chapters; an appendix on sources; an extensive bibliography on county, state, and federal archival materials; and many historical maps and photographs.

Although this study did not originate in a new data set, the fortunate discovery of a set of documents that had never been used before in studies of California's agricultural history provided impetus to the study. The author's experience in locating these documents is an excellent example of dedicated scholarship. The data dictated the scope of this research. The study begins in 1860 because it is the earliest date systematic data are available on Chinese in California agriculture, and it ends in 1910 because the role of Chinese immigrants had become more or less institutionalized by this date.

The first chapter establishes the thesis convincingly; namely, that the nineteenth-century Chinese emigration to California was only one aspect of a much larger immigrant stream—a Chinese Diaspora of truly impressive dimensions. Responsible for this massive immigration were both "push" and "pull" factors, the most important of the latter being the lure of gold. In the next few chapters the author gives a history of California's political fortunes; the important factors that determined the number of Chinese immigrants settling in California at different times; and the entry into, and later dominance of, the vegetable agribusiness by these immigrants. Truck gardening and vegetable peddling were the two agricultural roles the Chinese immigrants found most suitable. The last statement in chapter four captures the essence of this success story: "The Chinese had come to mine gold; for a few of them, the nuggets they found turned out to be green" (p. 157).

Chapter five examines the substantial contributions the Chinese farmworkers made to California agriculture. The reclamation and agricultural development of the New World Delta was done primarily with the help of Chinese workers. The author's examination of the relationship the Chinese tenants had with their landlords, the different patterns of tenancy, and the economics of Chinese farming in the delta

reveals the knowledge and dedication of the Chinese farmers.

The next chapter introduces the "Potato Kings"—Chinese tenants who had become so successful in the New World Delta area that they went on to become large landowners themselves. The contribution of Chinese farmers to the wine industry and their involvement in the cultivation of fruit and speciality crops is the focus of chapter seven. Chapters eight and nine discuss the literature on the controversial thesis that the cheap and plentiful supply of the Chinese farmworkers was responsible for the creation of land monopoly in California. The author shows that, contrary to this thesis, the Chinese farmworkers played "multiple roles" and were often far from docile. Chapter ten examines the contribution of the Chinese contractors and merchants, who, although not directly involved in farming, greatly facilitated its smooth operation. In the last chapter, the author shows that the view that the Chinese communities failed to assimilate with mainstream America because of their adamant refusal to give up their native culture is largely a myth. In fact, the successful Chinese communities in America were in many ways markedly different from the parent communities in China. Chan concludes that the real significance of the Chinese participation in California's agriculture lies in the legacy of the diverse and integral role they played in the development of the state's agriculture for six or seven decades.

The book is not without flaws, although these are minor in nature. A few typographical errors remain here and there. After studying the treasure trove of new information the author has unearthed, one cannot help but wonder if more sophisticated statistical analysis could have yielded stronger conclusions. I also find the role of Chinese women to be underreported. Did the Chinese women play any role in California agriculture? Was it economic or cultural barriers that prevented them from joining their men overseas? These questions are neither asked nor answered.

This is an important book. Scholars in diverse areas—history, sociology, political science, agricultural economics, labor economics, and public choice theory—will benefit from this work. Most important, the author's lucid presentation will ensure a much wider audience than the academic.

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Folmer, Henk, and Ekko van Ierland. *Valuation Methods and Policy Making in Environmental Economics*. Amsterdam, Netherlands: Elsevier, 1989, 259 pp., $89.00.

This book is a collection of twelve papers from a 1987 international conference on Environmental Policy in a Market Economy. Several common threads connect these papers and help this volume avoid what I call the "Old McDonald's Farm syndrome of edited volumes: here an essay, there an essay, everywhere an essay, essay." These common themes include the importance of knowing the public's value of environmental services to manage efficiently water quality (chap. 2 by d'Arge and Shogren), air quality/acid rain (chap. 5 by Navrud, chap. 6 by Dickie and Gerking, chap. 7 by Shecter et al., and chap. 12 by Maler), and renewable resources such as endangered species (chap. 3, Johansson) and forests (chap. 4 by Johansson et al.). The second major theme is methodological comparisons between a variety of hedonic methods (HM) and contingent valuation methods (CVM) for valuing water quality (chap. 2) as well as air pollution and human health (chaps. 6, 7) and mortality (chap. 8 by Herzog and Schlottmann).

The third theme of this volume deals with problems in performing cost-benefit analysis (CBA) in its currently practiced partial equilibrium form rather than in the more correct general equilibrium format. Chapter 9, by Johansson and Lofgren, deals with performing CBA in an economy characterized by disequilibrium prices and both classical and Keynesian unemployment. Chapter 10, by Nentjes, proposes a synthesis of CBA and macroeconomic impact models which he calls "Macroeconomic CBA." His approach involves CBA estimates of the direct benefits and costs of reducing pollution and then use of the cost data in a macroeconomic model to simulate the impact on aggregate economic activity, the general price level, and balance of payments. The third paper on this general theme is Randall and Hoehn's development of the types of errors in summing independently derived valuation estimates to arrive at a total value of multipart packages of public programs. While the authors' demonstration of these errors has recently appeared in the *American Economic Review* (Hoehn and Randall), this chapter provides suggested empirical approaches that can be used to adjust independent valuation estimates obtained in a partial equilibrium framework.

The chapters in parts 1 and 2 of this volume represent a snapshot of several environmental valuation research issues of the 1980s: valuing nonmarket resources under uncertainty (chap. 3 on alternative levels of preservation of endangered species), comparison of recreation use values with existence values for environmental improvements (chap. 5 on alternative fish populations associated with acid rain mitigation and emissions control), comparison of CVM with hedonic property value methods (chaps. 2, 7) and improving the microeconomic foundations of valuation methods (chaps. 6, 8).

This type of volume typically has two audiences: researchers in the book's topic area(s) and as a supplemental reader in graduate courses. This book fills a small niche for each of these audiences. For researchers interested in uncovering a wealth of unpublished empirical valuation studies, particularly in the Scandinavian countries, this book is worthwhile. For researchers interested in state-of-the-art valuation methodology, this book contains little that has not

already been published by many of the same authors in journals or other books. From a graduate student's point of view, however, this book provides some logistical and expositional advantages over the original journal articles and books. The exposition in this volume of hedonic models, predichotomous choice era CVM and general equilibrium and disequilibrium issues in CBA would be more understandable than the often terse journal article counterparts. Thus, if one had a graduate natural resources survey course or seminar that touched on this wide-ranging set of issues, this book would be a good match. However, for researchers and courses focusing primarily on environmental valuation, Mitchell and Carson's recent book on CVM provides far more depth, is more current, and provides a broader discussion of techniques (including the travel cost method, a commonly used valuation technique scarcely mentioned in Folmer and van Ierland's book).

In sum, I did find the book interesting reading and a useful reference work. It is rewarding to discover five new valuation case studies. Maler's "Acid Rain Game," which applies game theory to evaluate the potential for cooperation between European and Scandinavian countries, would serve as a good starting point for evaluation of other international environmental problems, such as maintaining genetic diversity or tropical rainforests. Thus, the book is a useful addition to an environmental economist's research library; it will invariably save future trips to the main library stacks. In this sense, the book's option price exceeds its purchase price.

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Kendrick, David A. *Feedback: A New Framework for Macroeconomic Policy.* Dordrecht, Netherlands: Kluwer Academic Publishers, 1988, vi + 147 pp., price $29.50.

David Kendrick has been one of the leading lights in the development and application of optimal control methods to problems in economics. In this book he gives a verbal and graphical description of control methods, much like Stephen Hawking's description of physics and the universe. Unlike Hawking's book, Kendrick's subject is much narrower and much more readable to the uninitiated.

Kendrick's major topic is the concept of feedback. In a nutshell, feedback implies that the actions a manager or decision maker takes are functions of the current level of those variables describing the condition of the system under control. To illustrate this idea, the book uses the U.S. macroeconomy as its source of empirical examples. For example, he describes the unemployment compensation scheme recommended by the Council of Economic Advisors during the Kennedy administration, in which the level of benefits was tied to the level of unemployment in the economy at a given point in time. Benefits increased as conditions worsened, so the policy had the effect of an automatic stabilizer.

While the economy currently has several mechanisms that function as feedback rules, the book develops the proposal that more feedback mechanisms would be desirable. To advance this thesis, Kendrick presents a framework for deriving optimal feedback policies. This framework consists of setting goals for the economy, describing the dynamics (econometric model), and dealing with the uncertainty inherent in controlling any economic system.

As all modelers of large economic systems know, determining what constitutes an optimal performance is vague. Kendrick does not try to set such an agenda but shows how modelers can vary goals and then simulate the system and let policy makers identify the desired paths. Such an approach is certainly not an original proposal; but the author discusses how engineers, who have used control extensively, end up doing much the same thing. The net effect for economists is that they need not feel nearly as ad hoc as they might perceive themselves in undertaking such practices. One problem Kendrick does acknowledge is that for the U.S. economy there is not necessarily one explicit objective function shared by all decision makers (e.g., the president, Congress, and the Federal Reserve Board). How to address this problem and still derive feedback rules for the economy is not fully resolved.

In discussing dynamics of economies, the author illustrates the important impact of decision lags that characterize economic policy making. That is, recognition of a problem and resolving how to solve it are one type of lag in an economy as well as the lag in effectiveness once actions are taken. The former lag is a strong argument for more automatic stabilizers in the economy. In his conclusions Kendrick argues, "We have been experiencing a rough ride in the U.S. economy in recent years. Some of that rough ride was not necessary. Feedback rules could have smoothed the ride somewhat by providing frequent, quick, and small corrections to problems rather than infrequent, slow, and large policy changes" (p. 127).

A very forceful argument is made by the author for the use of confidence intervals in presenting forecasted results. The author acknowledges that uncertainty has an impact on macroeconomic policy through the effect of unanticipated events (e.g., the oil price rise), uncertainty about the true structure of an economy, and inability to observe the true state of a system accurately (e.g., the actual rate of unemployment). In describing some of the limitations of feedback methods, he discusses methods of policy formulation when there is uncertainty about which

model should be used to compute control levels when the true model cannot be definitively identified. Somewhat surprisingly, no discussion is given of the use of filters to estimate the true state of the system.

Other limitations of the control or feedback approach are recognized. In particular, the problem of agents in the economy (producers and consumers) reacting to policies in unanticipated ways is discussed. More formally, the problem is that of rational expectations, and the author recognizes some ways of resolving this. One is that such adjustments are relatively minor, so they can be ignored. Whether such a course of action is indicated is an empirical question that remains to be resolved. A second approach is to use game theory, and such approaches are comparatively complex. Simplification of game approaches may make such analysis empirically workable.

This is a short book and relatively easy and enlightening to read. Bright undergraduates would have no trouble understanding it. It was worthwhile also as a review of some big issues in macroeconomics. It is curious that nowhere in the book is feedback in an optimal control setting equated to how solutions are derived from stochastic dynamic programming problems. Nor does the book discuss the impact of uncontrollable exogenous variables. However, such criticisms are minor; the book is not meant to be inclusive of all aspects of feedback. It serves its purpose of educating the reader about feedback and suggesting interesting ways that feedback could be applied. The book is a good candidate for introductory reading in a dynamic optimization course, but not the main textbook.

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Lipton, Michael, with Richard Longhurst. *New Seeds and Poor People*. Baltimore MD: Johns Hopkins University Press, 1989, xiv + 473 pp., price unknown.

Michael Lipton and Richard Longhurst (LL) have an important message in this book: that agricultural research might be better directed at the needs of the poor if more deliberate efforts were made to think about the possible implications for the poor before the research were conducted. The book is directed at those who decide what agricultural research should be undertaken; and, although the title mentions seeds and the authors use their abbreviation for modern varieties (MVs) throughout, the book actually deals with the entire range of agricultural technologies and their impacts.

LL have reviewed an astonishing amount of literature to produce this broad-scale treatment of the effects of technological change in developing country agriculture. They begin with a description of varietal development, which amounts to almost a minicourse in plant breeding, then examine the distributional impact of modern varieties, their impact on labor use, and their impact on nutrition. Dissatisfied with findings on the apparent direct effects, LL follow with a chapter that integrates the effects, ranging from neoclassical general equilibrium through political economy, the neolithic revolution, and finally to international agricultural research. This is followed by a chapter on the future of modern varieties covering the "four main challenges of the 1990s" for agricultural research: rural population growth, sub-Saharan Africa, biotechnology, and international issues. A final chapter draws conclusions.

Agriculturalists will be pleased that LL have many good words for agricultural technology. For example: "if social scientists had in 1950 designed a blueprint for pro-poor agricultural innovation, they would have wanted something very like the MVs: labor intensive, risk-reducing, and productive of cheaper, coarser varieties of food staples." For those wishing references to empirical support for this view, LL have chapters on the relationship of new technologies and farm size, tenure, labor use, consumption, and nutrition. In all, LL show that in the main, new agricultural technology has had a pro-poor effect.

However, LL have far more to say about future research because many developing countries continue to be populated by masses of poor, rural people. Why have the technological advances not drastically reduced the numbers of these poor people? In their view, because the green revolution was not revolutionary enough: "MVs are an evolutionary technique not one that requires (or stems from) a transformation of rural power. An evolutionary technique—especially if used first by richer, less risk-averse farmers, with better access to information and inputs—tends, when introduced into an entrenched power structure, to be used so as to benefit the powerful. . . . Social scientists now see more threats to poor people's food access, whether from population growth or from technical change, as operating to reduce entitlements to food, whatever the impact on its availability" (p. 401).

Despite this underlying difficulty, LL claim that "the scope of agricultural researchers for improving their impact on policy, and in particular on poor people, is quite large." In their view, agricultural researchers need to focus on seven issues (p. 403):

1. Establish clear, published research priorities that favor the poor and "encourage nonconformist and interdisciplinary challenges to current research paradigms." 2. Those priorities would "consolidate, extend and redirect past improvements in the efficiency of food plants in handling water, nutrients, light and pests." 3. Those efficiency gains cannot be achieved in the short run if they are not sustained and lead to reduced efficiency in the long run. 4. The weak impact of MVs on certain crops or in certain agro-ecologies endangers many poor people and should be re-

dressed by agricultural researchers. 5. Agricultural researchers should be more concerned with improving food "entitlements" of the poor and not so concerned with increasing food "availability." 6. Agricultural research requires a more appropriate approach to human nutrition—"protein requires much less emphasis from researchers, the energy needs and absorption of vulnerable groups, much more." 7. International and national agricultural researchers will have "to develop new approaches in natural and social sciences; greater readiness to analyze the interactions of MVs with total systems (of power, of ecology, of economic transactions); and more awareness of history."

This reader is left wondering whether LL have more faith in the capacity of agricultural technology to address issues than is justified. They seem to believe that just about any desired social change can be produced by changing plants. An annoying characteristic of the book is its errors about technical agriculture; one hopes the mistakes do not cause technically knowledgeable research managers to turn away. For example, the green leafhopper, not the brown planthopper carries tungro virus (p. 80). Oryza nivara is but one of many species of wild rice, not "the wild rices" (p. 93). Bacterial nitrogen fixation uses nitrogen from the air, so it is puzzling to read a plea for research that is "less soil-extractive than bacterial nitrogen fixation" (p. 375). One only wishes that the Food and Agricultural Organization of the United Nations did, indeed, collect "standardized farm management data" (p. 141), for then much of the gymnastics required to compare studies across countries would be unnecessary.

I had difficulty with two other characteristics of the book: It makes frequent use of interjectory and parenthetical phrases, sometimes in combination; and it is written in a style that raises a problem in one sentence or paragraph, then knocks it down in the next. On issue after issue, one gets the sense of observing an intellectual tennis match with exhausting relays but no decisive point. Finally, sentences are unduly long and complex: no reader should be made to suffer through ninety-nine-word sentences with thirteen punctuation marks!

LL have a message that might, if readers could get to it, influence the way agricultural research is carried out. Unfortunately, it is unlikely that this book will have that effect.

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National Research Council, *Alternative Agriculture*. Washington DC: National Academy Press, 1989, 448 pp., price unknown.

This book, *Alternative Agriculture*, could well be the landmark publication heralding a new decade in which concerns for the environment will shape an alternative philosophy of farming. It is a report of the Committee on the Role of Alternative Farming Methods in Modern Production Agriculture by the prestigious Board on Agriculture of the National Academy of Science. This Committee of highly respected scientists from land grant universities and other public and private institutions was formed in 1984 to study the science and policies affecting adoption of alternative production systems in the United States. Their report has given scientific credibility to the concept of an alternative agriculture and has become the focal point of debate between critics and defenders of conventional systems of farming.

The first chapter of the book, agriculture and the economy, outlines the trend in American agriculture toward larger more specialized farming operations. Government policy, including agricultural research and education, is seen as a major factor supporting this trend. Greater specialization and larger farm size have been means of achieving greater production efficiency. "The primary goal of agricultural research and education policy has been to increase farm production and profitability while conserving the natural resource base. Achieving higher crop yields per acre has traditionally been viewed as the best way of doing both" (p. 77).

The second chapter documents a litany of unanticipated problems that have arisen as specialized farming operations have become increasingly dependent on external purchased inputs such as commercial fertilizers, synthetic chemical pesticides, animal antibiotics, and borrowed capital. Financial vulnerability, loss of genetic diversity, water quality risks, soil erosion, food safety risks, and rising input costs are among the problems the committee associates with conventional systems of farming.

The third chapter outlines science and research that supports alternatives to conventional systems of farming. Alternative agriculture is characterized as "a systems approach to farming that is more responsive to natural cycles and biological interactions than conventional farming systems" (p. 135). The committee states that "alternative farming is based on a number of accepted scientific principles and a wealth of empirical evidence" (p. 135). A representative sample of principles and evidence is provided under such headings as crop rotations, plant nutrient management, tillage, soil biota, animal health systems, and pest control in crops, with each section focusing on alternatives to commerical inputs.

In chapter four an attempt is made to assess the economics of alternative farming systems. The committee recognizes the lack of empirical studies comparing profitability of alternative whole-farm systems. They rely instead on evaluation of farming practices and methods typically associated with alternative agriculture such as integrated pest management, diversified farming systems, crop rotations, and lower costs of purchased inputs. They conclude that "research has begun to demonstrate the economic benefits of alternative farming systems and how current policies impose incentives and disincentives for

selection of various types of farming systems" (p. 241).

Section two of the book outlines eleven case studies that illustrate a range of alternative farming systems currently in operation in the United States. The committee makes no claim that these case studies provide scientific evidence that alternative agriculture could replace conventional agriculture in the United States with no sacrifice in productivity or profitability. The case studies are used instead to illustrate that a wide range of alternative farming systems have been found to be successful under actual farming conditions.

They conclude that "farmers who adopt alternative farming systems often have productive and profitable operations." But they also state that "research should be undertaken to predict the long-term impacts of various levels of adoption of alternative farming practices" on all aspects of agriculture and rural communities (pp. 8, 23).

The book is well written and uses terms that will be easily understood by most agricultural scientists, regardless of disciplinary training. This book is must reading for agricultural economists or anyone else who seriously wants to understand the current issues of agriculture and the environment.

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Parikh, Kirit S., Gunther Fischer, Klaus Froberg, Odd Gilbrandsen. *Towards Free Trade in Agriculture*. Dordrecht, Netherlands: Martinus Nijhoff, Publishers, 1988, xi + 357 pp., price unknown.

This four-author monograph is the detailed report of a major research project to quantify the likely effects of an outbreak of free trade in agricultural products. World-wide in scope, this effort was mounted by analysts of the International Institute for Applied Systems Analysis (IIASA) located in Laxenburg, Austria. At the book's writing, the authors were all staff members of the Food and Agricultural Program within the institute. The central idea was to employ IIASA's vast linked system of eighteen national and fourteen country-group models to explore how various scenarios of agricultural trade liberalization, achieved through negotiation, might alter world prices, trade volumes, and a host of economic and social indicators in affected nations, rich and poor alike. The potential connection between the content of this book and the ongoing GATT Round of multilateral trade negotiations ought to be patently obvious to anyone even mildly familiar with today's international trade policy debates.

The models which are stitched together to form the webbing of this estimated system are general equilibrium in form with their main focus of empirical detail in food and agriculture. Consequently, they feature rather aggregate relations in their industrial and financial sectors. Still, they are general equilibrium and trade balancing in both the national and international arenas. National and regional price, production, and trade policies for agriculture are built into the original reference system so that the effects of their deliberate removal can be gauged.

Five basic trade liberalization scenarios were investigated and compared to a complex reference scenario. The latter was designed to reflect actual and assumed economic conditions in the 1980–2000 period including no overt moves toward freer trade. The five scenarios involve agricultural (and only agricultural) trade liberalization by (*a*) the United States only, (*b*) the European Community only, (*c*) the OECD nations only, (*d*) major developing nations only, and (*e*) all market economies.

Two broad categories of outcomes were computed for individual countries whether or not they participated in a given liberalization scenario. The first is a set of specific outcomes in standard economic measures such as GDP, the trade balance, terms of trade, a food price index, total acreage harvested, and numerous others. The second is a group of "welfare" measures such as GDP per capita, calories per capita, life expectancy, numbers of hungry people, and two measures of relative income per capita. This second category does not include any of the standard consumer or producer surplus measures of modern welfare analysis.

A sensitive reviewer does not reveal either the outcome or full plot of a novel. In that spirit, I will not now give away the conclusions of this complex and admirable work. It is enough to say that the empirical results are mixed, yet not inconsistent with the major tenets of trade theory and most a priori reasoning about agricultural and trade policy. The results strengthen the view, widely held among economists, that agricultural trade liberalization is not likely to be an international welfare bonanza, but its achievement would be a worthwhile step forward.

The book begins with two introductory chapters that discuss basic issues in agricultural trade policy analysis, the character and extent of farm trade distortions in the modern era, and their impact on national economies. Most readers of this volume surely will be acquainted with this material from other sources, but its recapitulation here is not out of place.

The third chapter presents the analytical approach and attempts to make understandable the intricate mechanism of IIASA's linked simulation system. This is an important and very difficult task. In my judgment, the inherent complexity of the system got the upper hand on the authors. The reader of chapter 3, without other experience with these models, will not really learn how they are specified, estimated, and interconnected. One can obtain a general overview of the whole scheme and insight into the operation of a representative country model but virtually no specifics of any one model. This leaves the reader uneasy. It is not at all hard to identify this flaw yet very difficult to say how to fix it short of doubling the size of the monograph.

Chapter 4 is a detailed exposition of the basic reference scenario against which all the alternative liberalization packages are compared. It includes the base calculations of all the economic indicators and welfare measures employed in later analyses. The various liberalization scenarios are described and dissected in chapters 5 through 8. Chapter 9 contains a summary of the main findings and some not-very-sharp policy conclusions. Among the four technical appendices is a very helpful country-by-country synopsis of how the alternative liberalization schemes benefit or punish individual economies.

This book is written, organized, and set out in a professional, workmanlike manner. It contains huge gulps of data and results presented in seemingly endless tables. That the authors, nevertheless, were able to wrestle this material and their findings into a single, readable monograph is a remarkable and very useful achievement.

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Petit, Michael, Michele de Benedictis, Denis Britton, Martijn de Groot, Wilhelm Henrichsmeyer, and Francesco Lechi. *Agricultural Policy Formation in the European Community: The Birth of Milk Quotas and CAP Reform.* Amsterdam: Elsevier Science Publishers, 1987, 165 pp., $63.25.

Hollingham, Michael A., and Richard W. Howarth. *British Milk Marketing and the Common Agricultural Policy: The Origins of Confusion and Crisis.* Hants, England: Gower Publishing Co., 1989, 220 pp., $89.95.

Burrell, Alison, ed. *Milk Quotas in the European Community.* Wallingford, England: C.A.B. International, 1989, 214 pp., $45.00.

The reason for reviewing these three listed books simultaneously is evident from their titles. Milk quotas and the Common Agricultural Policy of the European Economic Community are two themes common to each publication. However, the publications reflect substantially different emphases and have only limited complementarity.

The basic objective of the Petit et al. book is to provide an understanding of why agricultural policies in developed countries are what they are. The complex decision process that led to the adoption of milk quotas by the EC in its March 1984 compromise reforming the Common Agricultural Policy is the "case study" chosen to bring insight to the policy development process. As such, a relatively intense review of the sequence of negotiations during the July 1983 through March 1984 period is described. The hierarchy of the decision process is specified in considerable detail across five of the (then) ten EC member countries, the Commission, the Council of (Agricultural) Ministers, and secondary parties. The five leading milk-producing nations in the EC—France, West Germany, United Kingdom, Netherlands, and Italy—were selected as foundation actors in the decision process. The book benefits from being jointly authored by academics from each of these countries.

In the early 1980s, it almost came to the point that if the European Community were going to survive, CAP reform of the dairy program was mandatory. Petit's book does a thorough job of scrutinizing the policy-making process in "the formation and confrontation of different national attitudes to these proposals, and the eventual emergence of a compromise agreement on the action to be taken" (p. 2). The authors advance the book as a research report as compared to a detailed assessment of the decision process. Hypotheses are advanced and concepts from oligopoly theory are utilized. However, the hypotheses actually are handled more as assumptions; and the conclusions chapter, therefore, moves in the direction of (*a*) summarizing some key elements of the CAP decision process, and (*b*) rationalizing the research processes utilized. As such, the reader is left to infer why policies are what they are from the total exposition. The book can be a useful reference for a graduate agricultural policy course.

The monograph by Hollingham and Howarth represents an excellent overview of the milk-marketing situation in England and Wales. The stated objective of the book is to provide "a factual description of the nature of the confusion and conflict existing [in the British milk industry] during 1985 and early 1986 and its manifold and frequently interrelated causes" (p. 4). In fact, the book serves a much broader usefulness in describing institutions, events, and market situations than either the title of the book or its stated objective imply.

There are seven chapters to the book. Chapter 2 highlights the dairy problem in the EC in the 1970s and 1980s—increasing supply/static demand—with useful detail on intervention milk price equivalent, export restitutions, co-responsibility levies—and finally the April 1984 adoption of the quota program. Chapter 3 traces in interesting chronology the development of marketing institutions and the changing structure of Britain's dairy industry from the failure of producer cooperatives in the price-depressed 1920s up through the increased production levels and tighter import restrictions as the U.K. moved toward its 1973 membership in the EC. A full chapter is devoted to the 1973–77 transition of the British milk industry into full compliance with the dairy program of CAP. The alignment of U.K. and EC prices required specific monetary measures. Also, the powerful role of the Milk Marketing Board in Britain was viewed skeptically by EC, and the Milk Marketing Scheme Legislation in Britain was amended to comply with EC policies.

The remaining chapters "constitute the core of the report and look at the liquid market and the manufacturing market respectively since Transition" (p. 5). Liquid milk was a complicating issue as Britain moved into the EC because liquid utilization in Britain in the early 1970s was 56% compared to a 17% average for the continental members. The chapter flows un-

evenly, leaving the reader uncertain as to whether changes are being forced by EC regulations or whether the dynamics of the marketplace are the catalyst. The chapter on Britain's milk-manufacturing industry initially addresses multiple pricing/cross-subsidization issues. Multiple pricing is an extension of classified pricing in that milk is priced not only according to product but is further priced according to the eventual market for that product. These issues are traced in revealing detail through arbitration and arraignment in the European Court of Justice. Students and researchers having a specific interest in milk marketing and dairy policy in Great Britain will find that the book provides an excellent history and overview.

The book entitled *Milk Quotas in the European Community* is easily the most useful of the three publications for the U.S. audience. For persons interested in dairy policy, supply management, and quota issues in general, the Burrell book should be must reading. With the advent of milk production controls in the EC in 1984 and the application of quotas in different ways among the member countries, the EC program presents a rich experience to draw upon in pursuing the do's and don'ts, and many of the short-run implications of quota programs in the milk industry.

The book is the proceedings (fifteen research papers) of a seminar held at the University of London in December 1988. Agricultural economists from seven of the more northern member nations author the papers. Papers are organized into four sections: (1) impact of quotas on milk producers, (2) implications of milk quotas to other farm enterprises and to the milk-processing industry, (3) quota transfer options and implications, and (4) aggregate impacts of milk quotas on the European Community.

The milk quota program currently in place in the EC will operate through 1991 and then be extended, modified, or terminated for 1992 and beyond. The 1984–91 system has essentially tied milk quotas to land so that quota transfer only occurs with land transfer. However, sufficient flexibility exists so that some member countries have effected rules for transfer arrangements through partial ownership transfer and through leasing schemes. At the same time, the French warn that the presence of quota markets becomes a major factor in forcing the permanence of quotas. Several of the presentations, at least implicitly, point toward the merits of going to a market system, Canada style, for quota transfer. There is general acceptance that the immediate objectives of the quota program have been accomplished: lower milk production, reduced (subsidized) exports, maintenance of dairy farm income, and reduced program expenditure. Concern with fossilization of the structure of the milk producer sector has diminished, although provisions generally have been directed at eliminating small operations, favoring medium-sized dairy farms, and placing some limits on large dairy farms.

Cessation (outgoer) schemes, somewhat similar to the Dairy Termination Program in the United States, have been a significant tool in freeing up quota initially, primarily to reallocate that quota for various restructuring objectives. Impacts on regional shifts, effects on other agricultural enterprises, equalization of levies to minimize penalties, and milk quota valuations are among other key topics addressed. Some of the important issues that will have to be addressed prior to 1992 are noted including (*a*) the market oriented CAP-GATT evolution versus the "permanence" of quota program, (*b*) problems with maintaining structural change over a longer time period with quotas, (*c*) excess capacity in the total agricultural sector, and (*d*) the basic problem of what price should be established as the quota price for milk.

In the United States, the issue of supply management in the milk industry is chronic. The European experience provides some fundamental insights to quota effects. Readers of this excellent volume should include everyone making inputs into dairy policy. Graduate courses in agricultural policy will find it to be a valuable reference.

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Portes, Alejandro, Manuel Castells, and Lauren A. Benton, eds. *The Informal Economy: Studies in Advanced and Less Developed Countries.* Baltimore MD: Johns Hopkins University Press, 1989, viii + 327 pp., $39.50.

The word "informal" means many things to many people. In this book, the term refers to activities which are "unregulated by the institutions of society, in a legal and social environment in which similar activities are regulated" (p. 12). Starting from this central concept of informality, the book reports on studies of such activities in Latin America (Guadalajara and Mexico City, Montevideo, Bogota, and La Paz), in the United States and Western Europe (New York, Miami, and Los Angeles; Valencia and Madrid; the Emilia-Romagna region of Italy; and Great Britain), in the Soviet Union, and in Penang State, Malaysia. Like most analyses of the informal sector, the focus of these studies is almost exclusively urban, although much informal activity undoubtedly takes places in rural areas.

The individual chapters report on primary research, much of it ongoing, on the characteristics of informal activities in these highly diverse circumstances. The authors come from several disciplines: sociology, political science, urban planning, and economics, among others. It is both the strength and the weakness of the book that the editors have not sought to impose consistency on the nineteen contributors. The result is a rich potpourri of ideas with a great diversity of approaches and methodology, of definitions, terminology, and ideology.

One of the continuing problems with the analysis of informality is that the concept is not easy to use in empirical research. One generally cannot tell by looking or by simple classification procedures whether an activity operates in accordance with all the rele-

vant regulations; this means that an interview is often required to determine whether an activity should be classified as formal or informal. It is often not a question of "yes or no" but of "more or less." This has led some of the contributors to adopt rules of thumb in their empirical work: informal enterprises are those with less than thirty workers (chap. 14) or less than ten workers (chap. 1). The discussion of the Soviet Union includes within the informal or "second" economy all production on private account, whether legal or illegal (p. 168, footnote 2). All of this leaves one uncertain about the precise set of activities that are really under study in the volume.

The individual contributions are uneven in quality. This reviewer found the chapters on Los Angeles and Miami (chaps. 6, 13), Uruguay (chap. 4), Bogota (chap. 5) and Italy (chap. 10) to be particularly interesting. For most readers, though, the most important contributions will be the first and last chapters, where the editors undertake a valiant if only partly successful search for generalities and commonalities among the diverse findings of their contributors.

The book makes clear the great variety of circumstances where production takes place outside of the regulations. In some cases, such activities have expanded in the face of—and perhaps in response to—widespread and onerous rules and restrictions (e.g., the Soviet Union); in other cases (e.g., the United States), one would be hard pressed to attribute the growth of informal activities primarily to an oppressive regulatory framework. In some cases, studies in the book suggest that informal activities have grown as a result of stagnation in the formal economy (Great Britain, Bolivia); in other cases, the most vigorous growth in informal activities has taken place in ways that are linked to dynamic growth among formal enterprises (Italy, Miami). This great diversity, well documented in the chapters of the book, helps avoid sterile questions as to whether informality per se is good or bad. Rather, one is led to ask about the circumstances under which informality is likely to be beneficial for the citizens of a particular city or region. The analysis makes clear the extraordinary complexity of the answer, influenced by a web of social, political, and economic forces which are only beginning to be understood.

Of course, the outcome of that inquiry provides the starting point for the next question: what are the policy implications? What should one do in order to promote desirable types of activities while controlling or restricting others? While this is neither the principal aim of the book nor in most cases the principal area of expertise of its contributors, the question is addressed obliquely in many of the chapters and is the subject of the concluding essay by the editors. Their answer is interesting and important. It indicates that, wherever informal activities have been successful in generating positive benefits to all participants (employers as well as workers), the state has made an important, positive contribution to that process. "A necessary if not sufficient condition for dynamic informalization is precisely getting the state *into* the economy in support of small-scale entrepreneurial initiatives. A positive official posture toward these activities, plus training, credit, and marketing support programs, emerge, in every instance, as a *sine qua non* for their development" (pp. 306). Warning against the danger of believing that the growth of informal activities provides a case for "getting the state out of the economy," they argue the need for "innovative state responses to a novel economic trend" (p. 307).

The studies reported in this book make clear that informality is not exclusively a third world phenomenon; rather, informal activities play a significant role in countries at all levels of development. A comprehensive analytical framework for the examination of such activities has not yet emerged. In the meantime, careful empirical studies, done without preconceived theoretical or analytical molds but encouraging diverse analysts to describe this part of the world as each sees it, may be the way forward. This is precisely what this book provides.

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Roberts, Ivan, Graham Love, Heather Field, and Nico Klijn. *U.S. Grain Policies and the World Market.* Policy monograph no. 4, Australian Bureau of Agricultural and Resource Economics. Australian Government Publishing Service, Canberra, 1989, xvii + 286 pp. (Available in the United States and Canada from ISBS Inc., 5602 NE Hassalo St., Portland OR, 97213-3640.) Price unknown.

This thorough examination of recent U.S. grain policy by the Australian Bureau of Agricultural and Resource Economics (ABARE) follows similar analyses by ABARE of the agricultural policies of the European Community (BAE) and Japan (ABARE). The purpose of these reports is to "contribute to the debate necessary to attain policy reform internationally, through provision of information and analyses" (foreword). This series of reports is aimed more to readers in the subject countries than to Australians. The premise behind the series is that objective analysis of domestic agricultural policy in the subject countries, aided by quality presentation, will help convince the target audience that present policy is flawed and should be changed—for the good of the target country. The fact that Australia would benefit from rational policy change in the subject countries is the justification for ABARE's considerable research investment in the three studies.

The authors make a significant contribution to the vast literature on U.S. grain policies. Most of the subplots of analysis in their story can be found elsewhere in that vast literature. To this they add their own original analysis, especially of international implications. They explain in economic terms how U.S.

grain policy works (emphasizing wheat policy in the 1980s), evaluate that policy relative to its stated objectives, and offer alternatives for the future. Their main contribution is to weave all the subplots together in an international setting to tell a story of a policy that, in their view, failed. Some U.S. analysts, however, would argue that they missed the Achilles heel of U.S. grain policy by stressing its world market implications. They would argue that it is the inequitable distribution of program benefits and the undesirable structural impacts on rural areas that would more likely lead to internal political pressure for change.

Their story is told in 171 pages of text, but the key points are developed with more rigor in over 100 pages of appendices. The text is divided into three parts. Part 1 gives an historical perspective to U.S. grain policy. Part 2 covers the international consequences of that policy, and how other grain exporters have responded. In part 3, U.S. grain policies of the 1980s are evaluated and policy alternatives for the future are proposed and evaluated. Part 3 concludes with a chapter on how the U.S. political process shapes grain policy.

The authors have written in a style to communicate to an audience with undergraduate microeconomic training. The transparency of their analysis is refreshing. In the appendix, the economic theory consists of diagrams of shifting supply and demand curves. Some single-equation models are estimated. Where they think that their analysis is based upon weak assumptions, they use sensitivity analysis. Thus, it is relatively easy for readers to follow the analysis and to identify assumptions and interpretations with which they might agree or disagree.

Here is a sneak preview of some of the conclusions. Policy analysts around the world debate whether U.S. grain policy actually increases or reduces grain output, i.e., do production controls offset the impact of production subsidies? The authors conclude that, "had US grain programs been discontinued from the beginning of the decade, aggregate US grain production from 1981 to 1987 could well have been much the same as it actually was" (p. 86). But they point out that during the 1980s the program costs were high for the U.S. Treasury and considerable instability was added to world grain markets. Policies stimulated too much production in the early 1980s. Consequently, surplus stocks were dumped on the market in the late 1980s in the form of generic certificates and Export Enhancement Program subsidies. The authors estimated that the latter caused a minor inconvenience to the EC and hurt Australian wheat growers. Their policy-of-choice for the future would be decoupled and tradable direct payment entitlements to producers.

I recommend the ABARE report to readers interested in understanding U.S. grain policy. It would be a good supplemental reading in an advanced undergraduate or M.S.-level agricultural policy class. A strength and unique feature of the book is the emphasis on international implications of U.S. policy as seen by analysts in a country that competes with the United States in that same market.

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Australian Bureau of Agricultural and Resource Economics. *Japanese Agricultural Policies: A Time of Change.* Canberra: Australian Govt. Pub. Serv. Policy monograph no. 3, 1988.

Bureau of Agricultural Economics. *Agricultural Policies in the European Community: Their Origins, Nature and Effects on Production and Trade.* Canberra: Australian Govt. Pub. Serv. Policy monograph no. 2, 1985.

Schmid, A. Allan. *Benefit Cost Analysis: A Political Economy Approach.* Boulder CO: Westview Press, 1989, 354 pp. $29.50.

Both the title and the W. J. Samuels' forward to Allan Schmid's book suggest a work that is much more narrowly focused than it really is. Although the coverage of the distributive issues that arise in cost-benefit analysis is quite thorough. *Benefit Cost Analysis: A Political Economy Approach* is comprehensive enough to serve as a general guide for those involved in public investment analysis and as a text for a course in applied welfare theory. Schmid states the theme of the book in the first chapter as one which, "instead of taking income and rights as independently given and to be implemented by benefit-cost analysis (BCA) in a Pareto-better fashion, we will see income, rights and the analytic rule of BCA emerge as interacting parts of the same structure" (p. 2). The author attempts this integration by working "out the practical implications of second-best theory, which accepts the fact that government cannot achieve desired distribution with lump-sum taxes and, indeed, that public spending is one instrument used to achieve a desired distribution" (p. 3).

Beginning with the second chapter, the book is organized in the same way that one might prepare a report on the costs and benefits of a public investment project. Chapter two is devoted to the theory of public investment in which the question of what types of investment should be made by the public, rather than the private sector, is addressed. Chapters three and four concern project evaluation, which Schmid defines as the identification of the inputs and outputs of the project. The next three chapters (5–7) examine the problems associated with assigning a monetary value to the various effects of a project. Chapter five discusses valuation of a project under the assumption that it will not alter current relative prices. Adjustments to such a valuation because of market failures is considered in chapter six. Chapter seven examines adjustments to such valuations for nonmarginal (price

changing) projects. Distributive issues inherent in any choice of projects are discussed in chapter eight, and alternative investment criteria and choice of the appropriate discount rate are the topics of chapter nine. Chapter ten discusses the effects of uncertainty. The final two chapters (eleven and twelve) discuss decision making in the political arena.

The author presents the material in a thoughtful and logical manner, which makes the book very readable. I found the discussions of consumer surplus (chap. 7) and the problems posed by budgetary constraints (chap. 9) especially well presented. Chapter 8, however, is probably the most thought provoking. Here, the author outlines his opposition to using equity weights to resolve concern about the distribution of benefits and costs. He argues instead that distributive issues must be resolved by assigning property rights. Schmid distinguishes, therefore, between policies that merely change the distribution of income and those that redistribute property rights (p. 158).

Few books (or reviews) are, of course, entirely above reproach. Although generally well written, the discussion is repetitious in some places and even confusing in a few others. (An example of the latter, on p. 168, is Schmids' description of free riding as the result of high transactions costs.) The terminology tends to become a bit eclectic in some instances. Examples of this problem in chapter two include the use of the term Pareto-better rather than Pareto-superior; the description of public goods as high exclusion cost, joint impact goods rather than goods with the characteristics of nonexclusion and nonrivalry; describing the compensation for loss of a property right as willingness to sell rather than willingness to accept payment; and the references to the truncation problem in empirical research as one where there is "a failure to control for the effects of maturation and testing" (p. 50). In all these cases, it might have been better if the author had indicated (as he does in other instances) the alternative terms for the concept under discussion. Finally, the bibliography could have been improved by including a greater number of the more recent works in benefit-cost analysis. (Works published since 1984 constitute only 6% of the total.) For example, inclusion of some references to William J. Baumol's work on the concept of fairness (see, for instance, his *Superfairness*, 1987) would seem appropriate given the importance Schmid affords to the interrelatedness of efficiency and equity questions. Nevertheless, I recommend Schmid's work both as a useful addition to one's personal library and as a text book in courses on applied welfare theory.

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Seibel, Hans Dieter, and Michael T. Marx. ***Dual Financial Markets in Africa: Case Studies of Linkages Between Informal and Formal Financial Institutions*****. Ft. Lauderdale FL: Verlag Breitenbach Publishers, 1987, 143 pp., price unknown.**

This book describes schemes to link informal and formal financial markets in Africa. The authors first present some conceptual considerations regarding the structure and characteristics of both informal (IF) and formal markets (FF). The latter fall under the control of the government, while the informal markets are atomized in size and scope and largely outside government control. Next, they summarize five case studies in four countries of linkages between formal and informal institutions under diverse economic and sociological conditions. The selected countries for case studies were Ivory Coast, People's Republic of Congo, Togo, and Nigeria.

The Ivory Coast is a liberal country with more than 9 million inhabitants and fifty to sixty indigenous ethnic groups. The focus of its agricultural policy is production for both internal consumption and export. The predominant informal financial institutions in rural areas are hired work associations, rotating savings and credit associations, and nonrotating savings and credit associations.

The People's Republic of Congo is a poor and underpopulated country with about 1.7 million inhabitants. Two types of IFs are practically universal in the country: rotating savings and credit associations and insurance savings arrangements, mainly for burial purpose. Some forms of IF were not found in rural Congo because of the low level of monetization. Women participate extensively in IF in rural Congo, and there are only four formal institutions in the country providing a limited amount of agricultural loans.

Togo is also a very poor country with about 3 million inhabitants. The major IFs are the rotating savings and credit associations, the daily deposit systems (*eye speakers*), and a combination of the two. The formal financial institutions in the country include several commercial banks, three development banks, one savings bank, and the national social security fund. The authors report that the formal sector has been largely unable to serve small farmers and small business people.

The size and complexity of Nigeria's economy and its large population pose a different scenario for comparison of formal with informal finance. The formal sector is characterized by a large number of state-registered cooperative societies. There are more than 17,000 of these cooperatives with 1.7 million members; the prevailing types are producers, marketing, and saving/credit cooperatives. The total number of members in IF groups in Nigeria, however, is estimated at 20 million. This shows a surprisingly strong dependence on informal financial markets, in spite of the expansion of FF in recent years. Also impressive is the large number of types and variations of IF in Nigeria.

The last two chapters in the book are the most interesting. In chapter 3 the authors suggest a way of

linking formal and informal financial markets. They stress the need to overcome the lack of personal relations between IF members and bank branches. They then propose a survey and mobilization campaign as a basic methodological tool tested both in Nigeria and Ivory Coast. The survey's purpose is to develop data concerning: (*a*) information on the existing IFs and their relationships with other organizations; (*b*) data on government development programs; and (*c*) insights on prevailing social, political, cultural, and economic conditions. Another purpose of the survey is to interest the potential participants of both sides (IF members and bank representatives) in considering linkages.

The last chapter provides guidelines for the development of formal and informal financial institutions in Africa. In the authors' view, linking informal and formal financial institutions requires changes in the concerns and behavior of the two parties. For the FF, such changes may be considered a downgrading; while, in the case of IF, these changes are mostly upgrading. Downgrading techniques of FF may increase the efficiency of banks, and upgrading procedures of IF may be carried out as a grassroots development strategy without the interference of banks. No formal ties are likely to exist between the two institutions.

The authors present some provocative suggestions regarding the activities and organizations of IF and FF. However, this section might have been expanded and developed in a more analytical fashion. Some of the suggestions are presented in a concise form and are likely based only on the authors' experience in financial development. The book contains useful information on informal finance and also provides suggestions on how to better link formal and informal financial markets in low income areas.

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Shaffer, Ron. *Community Economics: Economic Structure and Change in Smaller Communities*. Ames: Iowa State University Press, 1989, 322 pp., price unknown.

Microeconomic theory of the firm and consumer are the familiar building blocks of traditional economic analysis; Shaffer, in his book *Community Economics*, has undertaken the task of developing a similar set of basic tools for analyzing community-level economic activity. Because communities are composed of individuals and firms operating within a larger regional and macroeconomy, each of these theoretical orientations can contribute to our understanding of how communities function and how economic information can be used to improve their situation. This book is particularly timely given the current level of interest in rural development by national, state, and local policy makers as well as the critical nature of issues facing rural communities. The book narrows the discussion of community development to a focus on the role of economics in furthering community goals. It also differs from previous textbooks in the rural development field, such as *Micropolitan Development* by Brinkman and Tweeten, in that it offers many practical analytical tools for practitioners in the field.

The book's organization makes a logical progression from a review of regional economic development theories into an examination of the goals, policies, and programs to support economic development, followed by an examination of special topics in community economic development such as the role of government, capital markets, and the functioning of labor markets in community development. The concluding section deals with methods of analysis, including impact analysis, economic base, and input/output models.

While a theoretical background is important in guiding researchers, the lack of a generally accepted unifying framework for economic development has not prevented state and local economic development officials from pursuing a wide variety of economic development strategies. These strategies can be classified as guided by demand-oriented and supply-oriented theories according to the scheme presented by Shaffer. His review of theories focuses on those which have direct policy handles or relevance for state and local policy makers. However, the continuing problems of rural areas suggest that the current array of economic development theories is not providing appropriate guidance for policy makers. As an alternative, ideas, strategies, and theories from nontraditional sources, such as the international development field or other academic disciplines, need to be explored for potential to stimulate ideas on economic development in rural areas. Although Shaffer's section on components of a community economic development model raises critical issues that a comprehensive framework must address, he stays away from the challenge of developing that integrating framework in this volume.

Another challenge to achieving a generally accepted economic development framework is the fact that many practitioners in the community and economic development arena are heavily involved in organizational and implementation activities, while losing perspective of the theoretical foundations for their activities. While this book provides a reminder of the role and contribution of development theory for practitioners, Shaffer also provides several chapters on organizing and implementing community economic development programs. A practical corollary to the theoretical section is the discussion of five generic strategies to promote community economic development: (*a*) attract new basic employers, (*b*) improve efficiency of existing firms, (*c*) improve ability to capture dollars, (*d*) encourage new business formations, and (*e*) increase aids/transfers received from broader governmental levels.

Although fairly general, these five strategies are a

useful way to begin organizing and considering economic development choices. They also provide a recurring theme throughout the book.

Other practical information for community development workers is contained in the chapter on implementing community economic development programs such as organizing development groups, setting goals, prospecting, and targeting for industries. For business analysts interested in retail and service development issues, the book offers relevant discussion on central place concepts for small area analysis including: trade area analysis, gravity models, service and trade thresholds, and sales potential calculations.

Several important and controversial issues in community economic development are also given special discussion including the role of capital markets and the appropriate role for government in the economic development process. These topics have been debated extensively among policy makers and professionals in the economic development field, and Shaffer provides a well-rounded discussion and extensive bibliography on these issues.

While Shaffer provides a comprehensive and well-balanced discussion of the chosen set of issues, additional topics of vital concern to rural areas might also have been included, such as issues in the provision of public services and infrastructure concerns in rural areas. The best feature of the book is the scholarly blend of the theoretical foundation and principles of community economic analysis into a set of guidelines and tools for practitioners in this area.

Although this book is developed from classroom lecture notes, much of the material is based on Shaffer's years of community development experience. Very few books in the regional economics area are able to combine a comprehensive discussion of community economic development theory with positive, practical contributions to practitioners in the field. *Community Economics* should serve as a useful training and reference book for students, researchers, and practitioners in the community economic development field.

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Simpson, James R. *The Economics of Livestock Systems in Developing Countries*. Boulder CO: Westview Press, 1988, xxii + 297 pp., price unknown.

Simpson's book aims to provide a framework for evaluating livestock production investments in developing countries. He argues that livestock production is different enough to warrant separate treatment from standard analyses of agricultural investments. The book's audiences are technically oriented economists needing a general reference on the subject and animal scientists learning about economic approaches to their fields. I agree that the topic merits separate treatment and think the choice of audiences is appropriate, but I believe major revisions are necessary before the book finds a wide readership.

The book emphasizes cattle production, with secondary reference to swine, goats, and sheep. After introducing the intellectual background to his theme—systems analysis, research methodology—Simpson classifies cattle systems as extensive or intensive; the contrast between the two is the book's organizing theme. Within each class he lists the principal characteristics as activities (e.g., cow/calf or dual purpose), institutions, herd size, and feed systems.

Simpson then presents standard discussions of microeconomic theory, with case histories from agricultural production: enterprise budgeting, whole-farm analysis using programming techniques, and partial budgeting. Those techniques are applied to cattle systems in whole-farm analysis and subsequently to the problem of fattening cattle to slaughter weight. After reviewing production systems for goats/sheep, buffalo, and dairy cattle, Simpson reverts to the methodologies for capital budgeting, project analysis, simulation, and farming systems research. Simpson expounds the methods in enough detail that readers might usefully follow the book's examples in practical work, and this is its principal virtue.

The most general shortcoming in the technical chapters is failing to consider risk, either in project analysis or in choice of technique. While economists are obviously familiar with risk in project analysis (and have many good references on the subject), animal scientists probably are not. Also, the treatment of simulation is sketchy. It fails to distinguish between biological models and economic ones. Given that the data for simulations of biological processes are scarce in developing countries, Simpson might have presented methods and results of economic simulation models more thoroughly, especially in light of his intended dual readership.

Other specific deficiencies in the method chapters include a tendency to treat the herd size or stocking rate as fixed in investment analysis. This is not always right, especially in extensive systems where increasing herd size or stocking rate is usually the cheapest growth path. The book does not mention economies of scale in animal production, especially those associated with herding labor. The assumption that such economies do not exist is a vital one to linear programming, for example, and yet it is not noted at all. Nor is the joint production problem mentioned in extensive meat and milk production. The conflict between the two is decisive for herd management where milk is a subsistence good.

The book lacks perspective on how the choice of technique—its main theme—fits into the evolution of production systems. While the main classification is, rightly, intensive versus extensive systems defined by stocking rates, the book returns only intermittently to that theme. The choice of analytic technique is not seen as a function of the system studied. This situation is reflected in the production systems picked to show particular analytic techniques. The

case histories seem to have been chosen largely because they were available and sometimes contain discursive material that adds little.

There is not enough in the book on what makes poor economies unlike rich ones. Because the purpose of the book is to treat the developing country livestock industries separately from developed ones, this oversight is puzzling. Outstanding differences are higher transaction costs in factor markets, production diversification in response to those costs, and the absence of insurance markets (particularly for transactions in breeding stock). Simpson adduces disparate noneconomic objectives (pp. 29, 227, 230) but fails to prove that these objectives exist (e.g., prestige) or that they affect resource allocation ("prestigious" herd expansion inducing suboptimal offtake and overgrazing). With respect to the motives for herd expansion and low offtake, Simpson does not consider Jarvis's argument that what appear to be irrationally low offtake and overgrazing are really profit-maximizing responses to the low feed costs found in many poor countries. Another illustration of this failure to draw out the consequences of differences between rich and poor economies is the book's inadequate treatment of seasonality where input markets are thin or absent.

The bibliography omits such important works as Lovell Jarvis's book on Latin American livestock and Stephen Sandford's on third world pastoralism. It also has some annoying typos and is dated in a few instances.

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References

Jarvis, Lovell S. *Livestock Development in Latin America.* Washington DC: Johns Hopkins University Press, 1985.

Sandford, Stephen. *Management of Pastoral Development in the Third World.* Chichester: John Wiley & Sons, 1983.

Ward, Ronald W. and Richard L. Kilmer. *The Citrus Industry: A Domestic and International Economic Perspective*. Ames: Iowa State University Press, 1989, 180 pp., $22.95.

Ward and Kilmer's goals are to provide the reader with "insight into the infrastructure of the citrus industry . . . and to provide a case study illustrating the complexities typical of many agricultural markets" (p. vii). The book has ten chapters organized in four sections: I, "Production and Distribution; II, Pricing and Risk"; III, "Market Development, Industry Cost, and Value"; and IV, "International Trade." Although the authors refer to the book as a text, it may be more useful as a descriptive reference introducing the reader to the industry or perhaps as a basis for a case study.

A case study of the citrus industry could be useful for many reasons. Of particular interest are the six primary factors identified by Ward and Kilmer as causes of changes in the industry: (*a*) changes in processing technology, (*b*) Brazilian citrus industry growth and resulting increased international competition, (*c*) weather patterns (freezes), (*d*) consumer demand for convenience, (*e*) increased emphasis on brands, and (*f*) changes in market shares and increased government involvement in decisions (p. x). One might suggest that disease and pest concerns, i.e., citrus canker, Mediterranean fruit fly, may also be an important source of change in the citrus industry. Many other industries share the same change-inducing factors, and readers could learn a great deal from understanding how these factors have been interrelated to effect change in the citrus industry. While Ward and Kilmer urge the reader to "recognize the interdependence among these factors" (p. x), the authors should accept more of that responsibility. Indeed, at the end of the book, it would have been appropriate for the authors to give their appraisal of how the factors inducing change in the industry are likely to be interwoven to effectuate future change in the industry.

Much of the book is based on reviewed research papers and other works by the authors and other faculty members at the University of Florida, particularly those associated with the Economic Research Department of the Florida Department of Citrus. Other sections report research results that appear to have not been reviewed and may be available in unpublished mimeographs, staff papers, and consulting reports. The variety of sources used and the varying qualities of review to which those sources have been subjected make the book at times discontinuous and occasionally redundant. One example of the redundancy can be found on pages 82 and 139 where duty-drawback provisions and their implications are described.

It is difficult to describe the type of reader that the authors had in mind. Most of the book contains largely descriptive data with limited statistical analysis. Yet in tables 7.1 (p. 103) and 9.1 (p. 137) somewhat complex statistical results are presented with only limited explanations.

The book is data intensive. Of the 165 pages in the body of the book, there are 45 tables and 46 figures. This information is useful for reference purposes; however, at times I was moving through page after page of tables wondering where the next portion of text would occur. Many of the detailed data might have been placed in an appendix. A list of tables and figures would help the reader find information.

Some data series appear to end at approximately the time period when the cited studies were originally presented. While asking the authors to update the analyses that were previously completed would be unreasonable, it does appear that updated data could have been presented in several instances. The authors' assessment of the continued validity of results from the previously completed research studies would have been useful. Many of the series were complete

to the 1985/86 season, with occasional references to the 1986/87 season.

The usefulness of extensive review of Florida processor concentration as of 1978/79 (p. 21) without comparisons to updated information about Florida and other domestic processors as well as Brazilian processor concentration is difficult to justify. The industry has at least one additional major branded product and higher volume of reprocessing outside of Florida. Because of the changes, it is not clear that Florida is still a particularly useful market definition for which to measure concentration. The authors recognized this point when they suggested that "The ability of a few Florida processors to exercise price leadership is no longer possible (or has been limited) . . ." (p. 132).

The authors properly identify the significant role that the Brazilian citrus industry has played in determining the fate of the processed product industry in the United States. The book could have been improved by including more current information on the Brazilian industry. Much of the section describing the Brazilian industry is based on papers written in 1978.

Because of the extensive jargon used in the citrus industry and the number of organized groups in the industry, it would also have been helpful if the authors had prepared a glossary of terms and industry organizations for inclusion in the book. Examples of the types of confusion that could have been clarified by a glossary are the authors' referrals to the Florida Canners Association, FCA, (pp. 50, 52, and in tables 3.1, 3.2, figure 4.3) whose name was changed to the Florida Citrus Processors Association, FCPA, as referenced in table 3.4. A glossary or appendix defining the various units of measurement used for both fresh and processed citrus also would have been useful.

The authors took on a challenging task in a dynamic industry that has changed rapidly. Because of the rapid rate of change, it is unlikely that anyone could write a book and have it as current as they would like at the time of publication. As a result, the usefulness of Ward and Kilmer's work is restricted primarily to that of a historical reference that leads the reader to many of the data sources and suggests many of the proper questions that need to be asked.

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Oklahoma State University

Errata

In the February 1990 issue of the *Journal*, there was an error in the article, "Utilization, Profitibility, and the Adoption of Animal Draft Power in West Africa," by William K. Jaeger and Peter J. Matlon, page 46.

The first sentence in column 1 under the heading "Previous Work Reconsidered: The Harvest 'Constraint'" should read as follows:

"The analysis presented here is consistent with most prior literature and field surveys, which generally found evidence of area expansion effects with the introduction of animal traction but only limited support for yield effects (Barrett et al., Sargent et al., McIntire, Lassiter).

The reference to McIntire was inadvertently omitted from the reference list. It should be:

McIntire, John. "Two Aspects of Farming in Central Upper Volta: Animal Traction and Intercropping." *ICRISAT Village Studies Rep. No. 7.* Ouagadougou, Republic of Upper Volta, 1981.

The second group of errata are for errors in the May 1990 issue of *AJAE*, in article number 1, "Preferences of Citizens for Agricultural Policies: Evidence from a National Survey," by Jayachandran N. Variyam, Jeffrey L. Jordan, and James E. Epperson.

On page 259, table 1, statement 1 should read:

"The family farm must be preserved because it is a vital part of our heritage."

On page 261, equation (1) should read correctly:

$$\eta = \Gamma X + \zeta,$$

Finally, on page 262, equation (3) should read:

$$\Sigma = \begin{bmatrix} \Lambda \Gamma \Phi \Gamma' \Lambda' + \Lambda \Psi \Lambda' + \Theta & \Lambda \Gamma \Phi \\ \Phi \Gamma' \Lambda' & \Phi \end{bmatrix},$$

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The American Agricultural Economics Association (AAEA) seeks to further the systematic development of knowledge of agricultural economics in order to improve agriculture and agriculture's contribution to the general economy.

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—publishes the *American Journal of Agricultural Economics*, the *AAEA Newsletter*, *Choices*—The Magazine of Food, Farm, and Resource Issues, and, periodically, a *Handbook-Directory* of AAEA members;
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American Journal of Agricultural Economics

Volume 72 • *Number 5* • *December 1990*

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AAEA Annual Meeting
Kansas State University
Manhattan, Kansas
4–7 August 1991

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American Journal of Agricultural Economics

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Gordon C. Rausser

Walter P. Falcon

1990 Fellow

Helen C. Farnsworth Professor of International Agricultural Policy, Stanford University, 1976–present.

Director, Food Research Institute, Stanford University, 1972–present; Professor, Food Research Institute, and Department of Economics, 1972–present.

Senior Associate Dean, School of Humanities and Sciences, Stanford University, 1988–present; Associate Dean, School of Humanities and Sciences, 1985–88.

Deputy Director, Development Advisory Service, Harvard University, 1970–72; (Director of Research, 1966–70); Assistant Professor, Department of Economics, Harvard University, 1963–66.

Chairman, Board of Trustees, International Rice Research Institute, 1989–present (Member, 1987–88); Member, Board of Trustees, International Maize and Wheat Improvement Center, 1980–87.

Member, Board of Trustees, Winrock International, 1984–present; Chairman, Board of Trustees, Agricultural Development Council, 1979–83.

Member, Presidential Commission on World Hunger, 1978–80.

AAEA Quality of Communication Award, 1984; AAEA Award for Outstanding Article in the *American Journal of Agricultural Economics*, 1971.

Editor, *Food Research Institute Studies*, 1977–present; Advisory Council, *CHOICES*, 1986–87; Editorial Council, *American Journal of Agricultural Economics*, 1968–72; Associate Editor, *Quarterly Journal of Economics*, 1963–72.

Consultant, Agency for International Development, Ford Foundation, International Bank for Reconstruction and Development; Senior Food Policy Advisor, Government of Indonesia.

Walter P. Falcon has compiled a distinguished record of research, teaching, administration, and service in the international agricultural policy and development arena. Born in Cedar Rapids, Iowa, Falcon received his B.S. in agricultural economics from Iowa State University. He went on to Harvard University, where he earned M.A. and Ph.D. degrees in economics. Falcon remained at Harvard for nearly a decade, first in the Economics Department as an assistant professor and then in the Development Advisory Service (now the Harvard Institute for International Development). In 1972, Falcon moved to Stanford University as director of the Food Research Institute.

Among Falcon's publications are six books and more than fifty articles, reviews, and reports. His research reflects a lifelong interest in and commitment to international economic development. Early work focused on Pakistan. He was a member of the White House–Interior Department Panel on Pakistan, whose 1964 report was one of the first modern analyses of the conjunctive use of surface and groundwater and its role in the agricultural development of the Indus Basin. In 1978, he co-authored a major retrospective look at both the policies implemented and the remaining problems in the Indus Basin.

Technology transfer issues have also figured importantly in Falcon's research. His 1970 as-

sessment, "The Green Revolution: Generations of Problems," was one of the first articles to bring together the controversial issues of production effects, marketing needs, and potential social consequences of technical change with the perspective of someone who had been involved extensively in the field.

Falcon also has been co-principal investigator of six studies of major commodity systems, each of which examined the objectives of national food policies, the forces constraining those policies, and the consequences of those policies on commodity trade and the prospects for country or regional development. Work on the cassava, corn, and rice market systems in Indonesia all resulted in books, as did the study of rice market systems in West Africa. The study of the political economy of rice in Asia comprised two monographs.

Hundreds of Stanford students have learned about American agricultural policy in his annual course. He is currently involved in a Ford Foundation project to revise the undergraduate curriculum at Stanford to include significantly more international material and perspectives. This year he added his own new course, The World Food Economy, for undergraduates. He has been the mentor, either formally or informally, to virtually every Institute graduate student. Falcon's commitment to teaching is perhaps nowhere more evident than in the series of short courses on food policy analysis he and two colleagues created for senior government officers from five ministries in Indonesia. Their lectures were the foundations for the award-winning book, *Food Policy Analysis*.

One of Falcon's most important contributions to the profession has been as an administrator, where he is truly an institution builder. As director of the Institute, he has undertaken major funding initiatives that have enhanced significantly the productivity and visibility of its faculty; have broadened its disciplinary core to include nutrition, demography, and resource policy; and have financed its commitment to training both first and third world economists. His abilities as an administrator have not gone unnoticed, either in the university where he is now senior associate dean in the School of Humanities and Sciences, or in the international community where he is now chairman of the board of trustees at I.R.R.I. and a member of the board of Winrock.

Perhaps the ultimate reflection of his many skills is in his continuing role as a senior food policy advisor to the Government of Indonesia. Because of his insightful analyses and forthright discussions of key issues, combined with remarkable interpersonal skills and the political sensitivities required of an expatriate advisor, Falcon has been invited to return every year for more than twenty to assist several ministers in the analysis of food and agriculture issues.

Together, Falcon's contributions are extraordinary—researcher and policy analyst, teacher and mentor, and administrator and institution builder. All are in the finest tradition of exceptional service by AAEA Fellows.

John E. Lee, Jr.

1990 Fellow

Administrator, Economic Research Service, U.S. Department of Agriculture, 1981–present
Member, Executive Committee of the Administrative Board, USDA Graduate School, 1983–present
Instructor, USDA Graduate School, 1983–present
Member, Executive Committee Social Science Agricultural Agenda Project (SSAAP) 1987–present
Member, Joint Council on Food and Agricultural Sciences, 1981–present
Member, USDA Committee on Biotechnology in Agriculture, 1987–present
Member, Great Plains Agricultural Council, 1981–present, member Executive Committee, 1986–89
Member, USDA Policy Coordination Committees for Science and Education and for Natural Resources and Environment, 1982–89
Member, Steering Committee, study of "Productivity in the Food Industry," President's Council on Productivity, 1972–73
Chaired AAEA Membership Committee, 1975–77
Editorial Council of AJAE, 1971
Director, National Economics Division, 1979–81; National Economics Analysis Division 1976–79; Commodity Economics Division, 1973–76; and Farm Production Economics Division, 1971–73, ERS/USDA
Chief, Agricultural Finance Branch, ERS/USDA, 1967–71
Agricultural Economist, ERS/USDA, 1962–67
Teaching Fellow in economics, Harvard University, 1961–62
Instructor and assistant in agricultural economics, Auburn University, 1958–59

John E. Lee, Jr., has influenced the agricultural economics profession through innovative leadership of the largest group of agricultural economists in the world. He provides inspiration and support for a wide range of activities of the American Agricultural Economics Association, effectively links work of agricultural economists in and out of the Economic Research Service with national policy making, aggressively advocates the importance of funding social science research and education in government councils, and champions the need for publicly employed economists to serve the common good by assuring widespread access to the information needed for enlightened public and private decision making.

John Lee has devoted his career to the U.S. Department of Agriculture's Economic Research Service. Starting as an agricultural economist working on production adjustment problems, he quickly gained the confidence of his colleagues and supervisors. In turn, he accepted increasingly important responsibilities as chief of the Agricultural Finance Branch, director of

four divisions, and, then in 1981, administrator of the Economic Research Service.

The premise guiding John Lee's professional career is that an informed public, aware of the full consequences of alternative courses of action will most likely assure that the agricultural and rural economies perform in the interests of the larger society. In that context, he argues that agricultural economists have special responsibilities to analyze implications of alternative public policies, technologies, and courses of action and to make these implications "transparent" to policy makers and the public.

Lee's commitment to excellence parallels his commitment to present unbiased research results in the face of controversy. That dual emphasis on excellence and independence has vastly increased the demand for and influence of ERS's work.

Lee's championing of research excellence and relevancy is mirrored by his support of professional activities including those of the American Agricultural Economics Association, the International Agricultural Trade Research Consortium, Resources for the Future, and the Great Plains Agricultural Council. He is an influential member of the Joint Council for Food and Agricultural Sciences and is an articulate spokesman in that Council and in USDA for the rural social sciences.

John Lee maintains a strong interest in education. He is a member of the General Administrative Board of the USDA Graduate School, serves on the board's Executive Committee, chairs the graduate School Futures Committee, and teaches a popular class in agricultural policy.

John Lee's commitment to public service, sustained professionalism, superb managerial skills, and innovative leadership account for his record tenure as administrator of the Economic Research Service and his success in enhancing the reputation of that agency in difficult times.

Gordon C. Rausser

1990 Fellow

Robert Gordon Sproul Distinguished Professor, University of California, Berkeley, 1986–present.
Chief Economist, U.S. Agency for International Development, 1988–90.
President, Institute for Policy Reform, 1990–.
Co-founder, Economic Development Consortium and A.I.D. Research Fellow Program, 1989.
Chairman: Economic Review Council, University of California, Berkeley, 1987–88.
Fulbright Scholar, Australia, 1987.
Sr. Staff Economist and Special Consultant, President's Council of Economic Advisers, 1986–87.
Assistant Professor: Department of Agricultural Economics, University of California, Davis, 1971; Associate Professor: University of California, Davis, 1972; Professor: University of California, Davis, 1974; Department of Economics, Iowa State University, 1974–75; Graduate School of Business Administration, Harvard University, 1975–78; and Department of Agricultural and Resource Economics, University of California, Berkeley, 1979–present.
Visiting appointments: University of Chicago, 1973–74; University of Illinois, 1972; Hebrew University, 1978; Ben Gurion University, 1978; Ford Foundation Visiting Professor, Argentina, 1972.
Senior Fellow, Resources for the Future, 1985.
AAEA Quality of Research Discovery Award, 1976; Honorable Mention, 1980; AAEA Quality of Research Discovery Award, 1986.
AAEA Outstanding Journal Article Award, 1982.
WAEA Outstanding Published Research Award, 1978.
Chairman, Department of Agricultural and Resource Economics, 1979–85.
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Faculty Excellence in Teaching Award, Harvard University, 1978.
Editor, *American Journal of Agricultural Economics,* 1984–86; Editorial Council, 1977–80.
Editor, *Advances in Agricultural Management and Economics,* Springer-Verlag, 1988–present; Associate Editor, *Journal of Dynamics and Control,* 1978–82; Associate Editor, *Journal of the American Statistical Association,* 1973–82.
Chairman, Vice-Chairman, and Secretary of the Western Agricultural Economics Research Council, 1980–83.
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Research recognition awards from national and international organizations exceed 14 (1976–present).

Research advisory committees or task force assignments for 15 U.S. and foreign governments, ministries, departments, or agencies (1978–present).

Keynote speaker or plenary session presenter exceeds 35 at major scholarly research conferences or symposia (1976–present).

Gordon C. Rausser, Robert Gordon Sproul Distinguished Professor, University of California, Berkeley, has become one of the major statesmen of our profession. A man of boundless energy, his cumulative and continuing contributions have established him as a world-class professional. Rausser was reared on a farm in California's San Joaquin Valley, a farm he managed from 1967 to 1973. He received his Ph.D. degree from the University of California, Davis, in 1971, and at that same institution he held his first professional appointment.

Over the course of his professional career, Rausser has become one of the effective and demanding mentors of Ph.D.s in our profession. Moreover, he has been responsible for developing at least four new areas of research and has been one of the pioneers in another nine areas. As a result, in 1972, 1976, 1978, 1980, 1982, 1986, and 1987, he and his collaborators were selected to receive the Outstanding Published Research Awards by the AAEA or the WAEA.

He has written more than 200 scholarly contributions in such areas as applied econometrics; financial and monetary economics; industrial organization; natural resource economics; public policy and economic regulation; statistical decision and information theory; exchange rates and agricultural trade; macroeconomic linkages with agriculture; and, most recently, in the areas of political economy of policy reform and new institutional economics. In many of these areas, his Ph.D. students have received departmental, university, or AAEA Outstanding Dissertation Awards.

Rausser's economic research is of the highest order: (*a*) he was the first economist to apply adaptive control methods to public policy, which formed the basis for one of his major books; (*b*) his work in evironmental economics was the first formal incorporation of information and measure theory, treating explicitly the inherent dynamic and stochastic behavior of environmental stocks and flows; (*c*) his collaborative research on commodity futures markets represents one of the first empirical treatments of rational expectation formation processes; and (*d*) he was the first to vigorously examine endogenizing governmental behavior, constructing political preference functions, and conceptualizing PESTs and PERTs. He, as much as anyone else, has made the political economy of policy a relevant research area for our profession.

Rausser is an inspirational and enthralling speaker, a characteristic which has enhanced his leadership effectiveness in research, teaching, and administration. Only three illustrations of his leadership contributions will be cited here. First, during one of the most critical periods of the Berkeley department's organizational life, he served as chairman for almost seven years. He accepted his responsibility at a time when almost one-half of the faculty was still to be recruited and almost all of the physical capital needed replacement. His leadership was instrumental in selecting outstanding faculty, refocusing limited resources, raising private research funds, redesigning the instructional programs, and enhancing the department's credibility on the Berkeley campus.

Second, whenever crises have arisen on the Berkeley campus, Rausser is generally asked to serve in one capacity or another. In one instance, he chaired an economic review council for the entire Berkeley campus, emphasizing the Department of Economics. His council presented a number of recommendations that have led to a steady and remarkable improvement in the department's performance.

Third, of paramount importance has been Rausser's role in designing and forming new institutions; the success of more than one research center can be attributed to his intellectual leadership. For example, as Chief Economist of A.I.D., Rausser used his scholarly work in the political economics of policy reform to develop an extension program for its implementation, leading to the establishment of the Institute of Policy Reform, the Economic Development Consortium, University Centers of Research Excellence, and the A.I.D. Research Fellow Program.

The weight and significance of his contributions to scholarly research, academia, the U.S. government, international organizations and agencies, the AAEA and other professional economic and statistical associations, and to the development and nurturing of Ph.D. students and junior faculty members are extraordinary. His *pro bono* activities and his unselfish contributions to public service and university administration have few equals.

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Warren E. Johnston

1990–91 President

Professor, Department of Agricultural Economics, University of California, Davis, 1974–present
Assistant Professor to Professor, Department of Agricultural Economics, University of California, Davis, 1963–74
Director, American Agricultural Economics Association, 1985–88
Chairman, Department of Agricultural Economics, University of California, Davis, 1981–87
University of California Pacific Rim Program, New Zealand, 1989
Fulbright Research Scholar, New Zealand, 1976–77
Research Fellow, Alexander von Humboldt Foundation, West Germany, 1969–70

Warren Johnston was raised on a family-owned diversified crop and livestock ranch near Winters, California, just fifteen miles from the University of California, Davis, the university campus where he first completed undergraduate studies and where he would later spend his academic career. His father's family were early California pioneers; his mother's were immigrants from Czechoslavkia, giving him an early and abiding appreciation of his agricultural roots and an immense curiosity about people, cultures, and institutions. Undergraduate studies were interrupted by three years of military service, including graduation from the U.S. Army Language School in Monterey in 1954 and two years as an interpreter/translator in West Germany. He finally received his B.S. degree in agricultural economics from the University of California, Davis, in 1959 and subsequently earned his M.S. (1963) and Ph.D. (1964) degrees in agricultural economics at North Carolina State University under the direction of George Tolley.

His research interests have often followed his continued interest in farming and ranching and have included collaborative work with noneconomists, building on the early physical and biological science emphasis of his undergraduate training in pre-veterinary medicine and pharmacy. Mainly, his research has involved issues relating to the structure of commercial agriculture or to natural resources and often to those at the interface between agriculture and resources management and policy. Throughout his research career, his interests have included work on agricultural land markets, on the changing structure of U.S. and international agriculture, and on agricultural and natural resources policies. His research contributions included early inquiries in the economics of outdoor recreation, on economies of farm size, on energy use in agriculture, and on the economics of aquaculture. As an example of multidisciplinary research accomplishments, his work with researchers at the university's Bodega Marine Laboratory on the North Atlantic lobster (*Homarus americanus*) ultimately led to publication of *The Bioeconomics of Aquaculture*, a book in which Johnston and his co-authors sought to better integrate economic, biological, and engineering subsystems into a framework for evaluating aquacultural production systems.

Johnston's accomplishments include recognition as an Alexander von Humboldt research scholar at the University of Hohenheim, where he collaborated on the first economies-of-size study applied to West German crop farms. He has had two awards to support research at Lincoln University, New Zealand, first as a Fulbright Senior Scholar and later as a participant in the University of California's Pacific Rim Program, and he continues to study structural adjustments following the removal of subsidy and assistance policies to New Zealand agriculture. He has served on two committees of the National Academy of Sciences and participated in a joint workshop between the U.S. and Polish academies on environmental and ecological consequences of agricultural development.

Johnston's service to his university has included frequent academic governance, faculty, and administrative appointments in the department, college, and university. He has guided the department's graduate program, served as acting dean and as department chairman, was chairman of the Executive Committee of the Giannini Foundation of Agricultural Economics, has coordinated California Sea Grant Program activity in marine policy, and served on the Water Resources Center Coordinating Board.

Professor Johnston and his wife, Donna, a 4-H "sweetheart," reside in Davis, California.

Structural Change and the Recognition of Diversity

Warren E. Johnston

Our inability to understand what is going on in rural America stems from the fact that we have been unwilling to devote the necessary research resources to the structural problems to gain a comprehensive understanding of them. —C. E. Bishop

It's not a question of putting Humpty Dumpty back together again—much of the wall is no longer there. —Robert D. Muldoon, former Prime Minister, New Zealand (Tutwiler and Elliott, p. 49)

Perestroika is not a new reality for North American agriculture. Structural adjustments in agriculture, in rural communities and regions, and in economic activities associated with the production and trading of agricultural commodities are made frequently in response to recurrent changes in economic and political conditions. Increased interdependence of agriculture with other sectors within the national economy and worldwide (Tutwiler and Elliott) amplifies the need for understanding the consequences of structural change, including the organization and control of the sector. Macroeconomic and international external sources have also been acknowledged as among the major leading forces necessitating significant adjustments in the agricultural sector (Schuh 1976, Warley).

The theme of adjustments to changes in response to internal and external stimuli merits our attention as we consider agriculture, the empirical subdiscipline of agricultural economics, and the American Agricultural Economics Association. The hypothesis is that changes in agriculture and in rural areas have affected and continue to alter the subdiscipline of agricultural economics, changing the focus of research, teaching, extension, and decision-making activities.

Both agriculture and agricultural economics have become more diverse in major aspects of endeavor. A major challenge is to provide reasonable stability while adapting to change. The contemporary setting includes the potential of major restructuring of agricultural policies in developed western economies and the nearly certain restructuring of policies in the USSR and Eastern Europe. The paper concludes with a discussion of implications of structure and diversity characteristics of agriculture and of the profession of agricultural economics upon the association.

Introduction

We know that individuals and firms respond to stimuli, and so it is in response to the stimuli of past experiences, current interests, and challenges that I develop the perspective of this paper. Among recent stimuli is Jim Bonnen's (1989) description of agricultural economics as an empirical science "based on a balanced emphasis of (1) theory (including disciplines other than economics), (2) statistical and other quantitative measurement techniques, and (3) data." These three (theory, quantitative methods, and data) describe "the three-legged stool that supports empirical tradition."[1] My agricultural roots immediately reminded me of the classical three-legged milk stool of the sort usually found in antique shops. I also imagined how much more stable a three-legged stool would have been than the apparatus that we used on the ranch—a chunk

Presidential address.

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[1] Many facets of agriculture, agricultural economics and the association also seem to reveal or characterize themselves in triplets, e.g., the threefold characterization of agricultural economics research as disciplinary, subject matter and problem-solving (G. Johnson, Bonnen 1986), and the classical threefold characterization of teaching, research, and extension as the missions of a land grant university.

of 4 × 4 redwood fencepost with the 1 × 4 nailed to the top. The instability of our one-legged T-seat was particularly noticeable when one responded too quickly to the stimulus of a whisking tail in a muddy barnyard.[2]

A more enduring construct is that reasonable stability, with flexibility to make the right "move" at the right time are among the goals that we desire for the agricultural sector and within the practice of agricultural economics and our professional association. Most of us have much of our formal training in the discipline of economics. We are mainly applied scientists interested in agricultural and rural issues, many of which are interrelated with national and international economic and political policies. There are others whose interests run conversely, being primarily interested in national and international issues which are interrelated with agricultural and rural policies. Either way, the commonalty of our interests is agriculture, broadly defined. Our observations and interpretations of the real world or our visions of the future condition our behavior.

Our perspective of structural change and ability to recognize diversity depends crucially on the comprehensive understanding sought by Bishop. We need to understand and evaluate change with reference to an identifiable benchmark or baseline condition. But because baseline conditions also change, subsequent observations can be deceiving unless we periodically update our understanding of the condition from which change has ostensibly occurred.

To illustrate how what we "know," or what we think we know, changes over time and to serve as an introduction to an expanded discussion of changes in agriculture, agricultural economics, and the AAEA, table 1 presents a brief and selective description of the structural organization and performance of agriculture and the profession at three different points in time: (*a*) 1930, in the early stages of the Great Depression; (*b*) 1960, a period of relative stability following profound structural change induced by the Depression, World War II, and the Korean conflict; and (*c*) the 1989 status.

Structural change has been constant in its direction for both numbers of farms and their size. Farm numbers fell significantly over the six-decade period, and farms have grown in size, on average. In 1930, the census enumerated 6.3 million farms. Half fell from the roll by 1960, and there are now only about 2.1 million farms of all sorts, just one-third the number enumerated in 1930. Farm size grew slightly less than proportionately because of conversions or reversions of land to other uses.

Related agricultural endeavors also changed over time. Agriculture uses inputs and financing, processing, distribution, packaging, and transportation services, all originating beyond the farmgate. While both farming and food and kindred products manufacturing firms (the major manufacturing sector associated with agriculture) declined in number, the timing of their significant declines did not coincide. The number of food and kindred products firms changed little over the first period (1930–60) but were nearly halved in the next two decades (1960–82). Concentration and efficiency gains also led to larger firms, on average, with only a slight reduction in sector employment.

The demographics of rural areas changed significantly during both time periods. In contrast to the early agrarian nature of the United States still evident in 1930, farmers are a small minority in rural America today. Forty-four percent (53.8 million) of the U.S. population lived in rural areas in 1930, and the majority of them actually resided on farms. In 1960, there was the same number of rural residents (53.8 million), but because of national population growth the percentage of the U.S. population living in rural areas declined to 30%. The proportion residing on farms was only 7%. About 26% of the U.S. population now resides in rural America, nearly 10 million more than in 1960, while those living on farms now amount to only 2%. Within sixty years rural America has changed from having a majority living on farms, sharing agrarian values, to the present situation where about twelve of every thirteen rural residents do not live on a farm. One-quarter of the nation's population shares rural residency but holds widely divergent values and perspectives, not always sympathetic to agricultural interests.

Change has also occurred in the profession of agricultural economics. Association membership numbers increased fourfold between 1930 and 1960 in response to enhanced professional opportunities created by New Deal agricultural programs and by postwar employment increases in government agencies and at land grant universities. The majority of the membership still declared specializations in farm management, production, or marketing in the early 1960s. It now appears that only about one-quarter to one-

[2] A recent reading of George Ladd's monograph may have had something to do with the evolution of these thought processes; nevertheless, I implore you to hold him blameless.

Table 1. Representative Changes in the Structure of Agriculture and the AAEA

Structure Indicators	Units	Year 1930	1960	1989
Number of farms	(1,000 farms)	6,289	3,158[a]	2,088[b]
Average farm size	(acres)	157	352[a]	462[b]
Food and kindred products (SIC 20)				
Establishments	(number)	48,796[c]	41,619[d]	22,130[e]
Employees	(number)	n/a	1,699[d]	1,488[e]
U.S. population	(million)	123	181	249
Rural population	(%)	44	30	26
Farm population	(%)	24	7	2
AAEA regular/individual members	(number)	622	2,321	3,623
—with farm management, production, or marketing specializations	(%)	n/a	51[a]	27[f]
AAEA June 30 nominal assets	($1,000)	9	90	1,124
AAEA June 30 real assets	(1989 $1,000)	99	367	1,124
Real assets per member	(1989 $1,000)	159	158	310
JFE/AJAE submissions	(number)	n/a	203	337

Sources: 1930, 1959, and 1987 Census of Agriculture; 1931, 1958, and 1982 Census of Manufactures; Economic Report of the President; annual reports of the American Agricultural Economics Association and American Farm Economics Association.
[a] 1959.
[b] 1987.
[c] 1931
[d] 1958.
[e] 1982.
[f] 1987.

third of our membership reflect those same primary interests in 1989. The number of regular members and the number of *AJAE* journal submissions have increased proportionately (by about 50%) over the 1960–89 period, while real assets per member have more than doubled, permitting expansion of services to an increasingly sophisticated and diverse membership.

These changes, in rural American and within the profession, illustrate how the environment in which we operate as professional agricultural economists has changed significantly within this century. Because the cumulative impact of changes ultimately affects the nature and mix of association activity, the next section expands on selected characteristics of structural change and increased diversity in agriculture and rural areas.

Agriculture

There is abundant evidence concerning the nature, magnitude, and rapidity of structural change at farm firm, commodity group, state, and national levels (see, for example, Heady et al.; Carter and Johnston; Stanton; U.S. Senate; Brewster, Rasmussen, and Youngberg; Buttel, Lancelle, and Lee; Reimund, Brooks, and Velde; Wilkening and Gilbert; Reif; Hallberg et al.; U.S. Department of Agriculture; Brooks, Kalbacher, and Reimund). Most contributions are by agricultural economists; but other social scientists, in particular, rural sociologists, political scientists, and historians, have effectively participated as well. Canadian analysts have also contributed to the understanding of these phenomena in their own setting (Veeman and Veeman) and have made comparisons with the U.S. situation (Ehrensaft et al.), although Brinkman noted in the early 1980s that long-run cumulative implications of government policy on farm structure were not as generally understood for Canada as for the United States. Western Europeans have also contributed to the literature (Peters and Maunder, Gasson et al., Galeski and Wilkening, Shucksmith et al.). And more recently, we have been increasingly exposed to reports of the need for restructuring in Eastern Europe and the USSR (Galeski, Schmitt), where significant change is expected. The rather abrupt change and subsequent impact of "economic liberalization" policies in New Zealand reveal readjustment problems, some unanticipated, and structural consequences of the most abrupt policy change in recent history (Sandrey and Reynolds). Whether change will be equally abrupt in the emerging market economies of Eastern Europe, which are largely without adequate in-

frastructures and private property rights, is yet to be seen.

The last three U.S. farm bills (1977, 1981, and 1985) have required annual reports to Congress on the status of family farms. They contain a rich source of information providing an annual updating of structural change issues, including size, sources of income, ownership, financial characteristics, and economic performance of U.S. farms, in general. They synoptically trace economic conditions, policies, and consequences through the intense inflationary period of 1970s, severe financial stress in the sector in the early and mid-1980s, and the subsequent gradual improvement of economic outcomes forecast for the agricultural sector into the 1990s (U.S. Department of Agriculture).

Given the considerable documentation about structural change in the historical record, what are the merits of urging that additional attention be directed to the structure of agriculture? Two points are to be made. First, measures of central tendency do not tell the whole story about structural change as it is occurring in rural America—nor in firm or industrial performance statistics. Our major challenges often are those of responding to divergent rural clientele groups created by the diversity in farms and in the general condition of rural America. Heterogeneity seems to be an increasing phenomenon as firms and areas respond to external forces. That central tendencies are not the whole story is of no surprise to those drawn to the beauty of higher moments of statistical distributions. While arguments of higher moments do provide additional information, they also complicate analysis and generalizations, introducing margins for error and misinterpretation if not appropriately recognized.

Second, it is dangerous to overgeneralize from descriptions of well-understood structures close at home to those further removed. Significant geographical variation among U.S. census regions is shown in a recent USDA report (Brooks, Kalbacker, and Reimund), and the same is surely true in Canada.

As a small example of the dangers of overgeneralizing, consider table 2. Those of us in the West occasionally experience well-intended, but inappropriate, generalizations in pronouncements and policies emanating from east of the Mississippi and the Potomac. The table contains several common farm structure indicators from the most recent Census of Agriculture for U.S. agriculture and for California. Using the census definitions and given the common characterization of California's industrial agriculture, it is likely surprising to the eastern or midwestern expert that average farm size in California is smaller than the national average,[3] that there is a higher proportion of farms smaller than 50 acres and a smaller proportion greater than 500 acres in size in California, that a higher proportion reports a nonfarming principal occupation, and that California farmers report more days of off-farm work. California farms do have higher average values, do exhibit smaller proportions of individual or family types of organizations and higher proportions of partnerships and corporations, and do have higher proportions with sales of over $250,000. These seemingly conflicting observations reflect the complexity of comparisons involving California's growing numbers of small farms with those of lesser numbers of highly productive industrial farms of the type more commonly thought of as typifying California agriculture. Similar examples surely exist for other locales.

Diversity in Agriculture

Agricultural economists have long abandoned reliance on the concept of the homogeneous, single-product farm firm. Rightly so. The consequence of unrelenting structural change in rural America, among not only farms and farming-dependent regions but also among regions more integrated with other economic sectors, has increased diversity in organization and control of all forms of economic and social activity. We know that the agricultural sector now consists of a mosaic of specialized types of firms ranging in size and intensity from part-time operators of small farm units with only modest economic outputs, to large-scale, industrialized farms with significant economic presence in the agricultural sector and sometimes involved in nonagricultural activities, as well. The range of farm units includes commercial, part-time, and amenity farmers; they need not be mutually exclusive.

[3] Between 1974 and 1987, there was a 23% increase in the number of farms in California, while nationally there was a 10% decrease. The number of farms in all but the largest size group increased between the two censuses. (The decrease in the number of large farms may be related to requirements for commodity and water delivery programs.) In 1974, average farm size in California had been larger than that for the nation, but the significant increase in farm numbers in California together with an 8% decrease in the acreage of land in farms served to drop average farm size by 25%, and below the U.S. average.

Table 2. Selected Farm Structure Components, U.S. and California, 1987

	Units	1987 U.S.	1987 California
Average farm size	(acres)	462	368
Average value per farm	($)	289,387	583,668
Percent distribution of farm by acreage:			
Less than 10 acres	(%)	8.8	27.3
10 to 49 acres	(%)	19.8	34.2
50 to 179 acres	(%)	30.9	18
180 to 499 acres	(%)	22.9	9.6
500 to 999 acres	(%)	9.6	4.6
1000 to 1999 acres	(%)	4.9	3.1
Greater than 2000 acres	(%)	3.2	3.2
Percent distribution by type of organization:			
Individual or family	(%)	87	78
Partnership	(%)	10	15
Corporation	(%)	3	6
Other	(%)	<1	1
Percent distribution of farms by principal occupation of operator:			
Farming	(%)	54	50
Nonfarming	(%)	46	50
Percent distribution of farm operators reporting any days of work off farm	(%)	57	60
Percent farm operators working > 200 days off farm	(%)	35	37
Average market value of agr. products sold per farm	($)	65,165	167,300
Percent distribution of farms by value of sales:			
Over $250,000	(%)	4.5	11.5
$100,000–$249,000	(%)	9.7	9.1
$40,000–$99,999	(%)	13.8	11.2
$20,000–$39,999	(%)	10.8	9.9
$10,000–$19,999	(%)	12	9.9
$5,000–$9,999	(%)	13.2	10.2
Less than $5,000	(%)	36.1	38.3

Source: 1987 Census of Agriculture.

Similar diversity is found in other rural activities and among the majority of the rural population who live beyond the farmgate.

The recognition of this diversity amplifies the need for careful analysis of more complex issues and problems and certainly challenges those who seek answers for policy and decision makers. From the process of structural change emerge elements of diversity pertaining to the full spectrum of different types of farm units and sector support services and involving, as well, a rural population no longer tied as directly to primary agricultural production.

Growth in diversity is slowly dampening the political and economic importance of production agriculture in rural America. Rural populations increasingly hold views different from those of farmers about acceptable cultural practices and resource uses. Conflict about cultural practices, land use, water use, or externalities between rural nonfarm and agricultural interests occur more frequently and give rise to contentious issues at every level of government, from local to federal.

A Legacy of Commodity Policies

The continued focus on farm policy rather than a more comprehensive rural policy is a modern enigma, though food safety and environmental groups have joined with traditional commodity and agribusiness interests in more recent farm bill debates (Browne). Program benefits continue to flow disproportionately to the largest farms and landowners and to those supplying them with inputs and services. With decreased farm population and significant increases in

nonfarm rural residents, commodity programs have progressively less bearing on total economic activity in rural areas and on the general economic welfare of rural people.

Restructuring of U.S. farm policy, in response to widespread intent to move the international order to a market orientation and the necessity to meet cost-cutting targets, may bring an overdue test of our inordinate reliance on commodity programs. Like the milk stool example, more stability and flexibility might have characterized a more balanced farm and rural policy structure with people, resources and environment, and commodity legs, rather than having us balancing precariously on a single-legged commodity structure. Recognition of a more diversified institutional perspective might have also permitted the corpus of policy to shift gradually over time, putting more weight on the people and on the resource and environment underpinnings of rural areas. The whisk of world attention to commodity subsidy excesses may have us scampering to stay upright in the mire created by a too strong reliance on commodity policies.

More Abrupt Changes Ahead?

Impending change in the agricultural policies of both developed and Eastern European economies may hasten the pace of structural change for U.S. agricultural producers, with significant implications for those associated with the sector and for all of rural America. Agricultural economists will be challenged to provide wise counsel in the many different settings.

Most of our understanding of structural changes induced by policies has been of the more gradual, rather than of the more abrupt, type induced by sudden shifts in economic conditions, particularly when those shifts have not been buffered by adjustment policies. New Zealand is a current case study of the effects of rather sudden economy-wide removal of government economic assistance programs. Less diversified than U.S. agriculture, New Zealand's export-oriented sector is dependent on, and subject to, vicissitudes of world markets. The shift in economic policies occurred because it had proven impossible to completely shelter the nation's economy from external forces, including those of increased international interdependencies in capital and commodity markets. Change was required because the legacy of progressive government assistance and intervention culminated in a large fiscal deficit, a heavy burden of overseas debt, and an inevitable decline in the standard of living. How much longer and at what continuing massive levels of expense can even the larger, more prosperous developed nations deny these realities?

Beginning in 1984, change came with policy moves to devalue the dollar, remove financial controls, eliminate subsidies and incentives, including tax deductions and investment allowances, and generally eradicate all forms of government intervention through financial assistance, regulation, or public ownership of enterprises. The largest New Zealand farmer organization strongly supported economic policy reform because of a belief that interest and exchange rate changes would be favorable to agriculture and that the export-oriented agricultural sector would ultimately prosper by a releveling of the playing field with respect to other sectors of the national economy.

Early analysis is now available describing the still evolving readjustment of the agricultural sector to the sudden removal of widespread public economic interventions in all sectors of the nation (Reynolds, Chiao, and Robinson; Johnston and Sandrey; Sandrey and Reynolds; Johnston and Frengley). Thus far, the experience with "economic liberalization" policies in New Zealand shows us that extensive change over a relatively short period of time is traumatic, that impacts are extensive (both in magnitude and duration), and that strong will and resolve are required to stay the course. Economic improvement has not been quickly or easily attained. Farm incomes declined. Improved income prospects engendered by better 1989 prices for dairy products, sheepmeat, and wool appear to be now threatened by the current softening of world market prices. Farmers who responded to distorted price signals and miscalculated the long-run risk of assuming continuation of assistance policies are bearing the brunt of the economic hardship, not unlike the fate of overcapitalized U.S. grain farmers in the early 1980s.

In New Zealand, continued high interest rates, weak exchange rates and commodity prices, and adverse climatic events have taken a heavy toll on the rural sector. Necessary adjustments in the ownership and capital structure of farm business continue. The restructuring of many farms either to rid them of excessive debt or to transfer ownerships at lower levels of capitalized values has been frustratingly slow. Six years after the return to market conditions began, insolvent firms continue to farm and the financial problems of

the most severely indebted firms have now shifted from borrowers to lenders. The economic character of New Zealand farming communities has changed dramatically as public services have been reduced or eliminated and economic conditions have altered profitability of local enterprises. The extent of the distress has permeated all of New Zealand, yet the resolve of farmers continues in anticipation of substantial benefits from current GATT negotiations. Their hope is that they will be among the earliest to be positioned competitively to take advantage of liberalized trade prospects in a world with fewer distortions. We can only wait to see if their venture towards unilateral dismemberment of agricultural subsidies bears fruit.

While abrupt changes appear likely in Eastern Europe, they are unlikely to have major near-term effects on international commodity markets, largely because of an overriding need to meet domestic demands and because of a lack of public infrastructures to support especially rapid structural change. Reestablishing private property and family farm units (Schmitt) and establishing appropriate infrastructures present a challenge. The primary mission is to reestablish an agricultural sector capable of responding to price signals, and careful design of evolving institutional structures will be required for the successful development of a productive private agricultural sector. Overzealous promotion of the merits of a market economy may neglect adequate provision of public infrastructure investments required to support sector development and efficiency. It may also obscure the recognition that nonmarket "bads" (e.g., environmental degradation) may accompany sought-after market "goods" in the process of agricultural growth and development and that integration of agricultural and environmental policies is desirable (Johnston 1990). We now understand that the environment was not husbanded prudently under previous communist regimes (Ryszkowski); it would be tragic if it continued to be abused under Perestroika.

There are some positive probabilities that change in agricultural sectors could be more abrupt than our recent experience. A significant challenge, whether the economic or policy change be of the incremental or of more abrupt type, is to understand clearly the implications for structure, interpreting outcomes not only with respect to sector productivity but also with increased sensitivity to resources and people associated with agriculture, its related economic activities, and rural areas. The consequences of these changes can influence the organization and practice of agricultural economics.

Agricultural Economics

Not all efforts to examine agricultural economics and agricultural economists are devoid of humor (though most are). In a notable exchange of wit and analysis, Roger Gray and Bob Firch once described the ecological dependence of black-footed ferrets and prairie dogs. In the Gray-Firch interchange, prairie dogs are farmers and black-footed ferrets are agricultural economists. They pondered, among other things, how the systematic reduction of prairie dogs could occur with the simultaneous preservation of black-footed ferrets. Two decades later, we observe that agricultural economists have not only maintained their numbers, but their population has increased. Evidently black-footed ferrets have found new ecological niches within which they can survive. They have, in essence, expanded their dependency beyond just prairie dogs to include suburban rodents and sometimes their urban cousins, as well.

Agricultural economists have increased in number because they have adapted to broadened views of what is a relevant focus for their professional capabilities. The empirical science of agricultural economics has evolved from applied problem-solving interests to a more mature disciplinary, subject-matter, problem-solving paradigm. The evolution has not been without repeated internal scrutiny (see, for example, Farrell, Phillips and Dalrymple, Stanton and Farrell, Harl, Schuh 1984, Swanson, Hoch, Havlicek, Padberg, Rasmussen, Hildreth et al., Bonnen 1988, Just and Rausser).[4] Much of past serious debate has been over the ideal paradigm mix required to gain status, to accomplish objectives, and/or to maintain accountability. Our existence as only a field or subdiscipline has, to some, cast shadows of inferiority and raised questions about our reason for being. To others, the existence of applied research problems in agriculture and in rural areas, together with the

[4] The overview statement for the Iowa State postconference on "Agriculture and Rural Areas Approaching the Twenty-first Century" begins with: "Whatever else may be said about agricultural economics as a profession and the American Agricultural Economics Association as a professional society, it certainly must be granted that they are willing to engage in self-examination to better evaluate their future and to explain their needs to others. This . . . is far from an isolated example" (Castle and Hildreth). The report of the self-examination then goes on to fill about 550 book pages!

primary empirical underpinnings of agricultural economics and nonbinding disciplinary strictures, continues to open opportunities for meaningful professional contributions.

The elements providing unity for agricultural economics are (*a*) a concern with the empirical and (*b*) an appreciation of economic theory (Castle). We are no longer just farm economists, viewing microeconomic analysis and advice for the farm firm as the sole domain for our professional contributions. We have increasingly moved from single advocacy of farm issues to include consumer, taxpayer and public views, incorporating an expanded vision of opportunity for problems and issues "beyond the farmgate," analyzed at appropriate levels—local, state, national, international.[5]

Changes in agricultural economics are a reflection of the integration of the agricultural sector with national and international economies, but consequences of responding to a wider range of opportunities may present difficult dilemmas for individuals and institutions. To some, the broadened perspective involves a loss of identity, a subdiscipline or field losing its way. The alternative is to view agricultural economics as an applied profession responding to cumulative agricultural and rural changes and increased diversity, mirroring our professional capabilities with the emerging problems and issues as we best can identify them within the disciplinary, subject-matter, problem-solving paradigm.

There is creative tension. Diversity in individual and institutional views regarding the proper domain of agricultural economics will persist because of variations in problems definition, commitment, and expectations as they pertain to goals and mission objectives. Management and accountability for this expanded opportunity set present new challenges, but so will the potentials for significant improvements in our understanding of broader segments for agriculture and rural America.

Implicit is the premise that the subdiscipline or field of agricultural economics is primarily research orientated. Our applied empirical science orientation is reflected not only in the research milieu but also in the nature of our undergraduate and graduate programs, in our extension commitments, and serves as the basis for employment in private industry, in government service, and as consultants. Responses to the question, "What is agricultural economics?" differ in the perspectives of colleagues, departments, and other institutions as they create or use agricultural economics research. The skill and knowledge base has expanded considerably to a much broader set of subject matter interests. Consumer economics, environmental policy analysis, industrial organization, finance, management, labor and human resources economics, international trade, economic development, marine economics, energy economics, economics of poverty, community development, and agribusiness are now among components included in land grand and USDA agricultural economics programs, with increasing contributions from other institutions, as well.

The diversity of emerging issues in agriculture and in rural America, and beyond, challenges the profession. Rather than anticipating significant issues and problems, changes in agricultural economics programs have been gradual and incremental, often lagging their emergence. Meanwhile, departments and colleges have shifted to more balanced research responses to agricultural and rural problems. Comparison of the 1956 and 1987 AAEA handbooks shows significant change not only in the identification of membership specialties, but also substantial change in the distribution of the membership among fields (table 3).

Recognition of emerging issues and concomitant staffing needs has increased hiring opportunities from other disciplines or fields, i.e., economics, business, statistics, operations research, sociology, in efforts to expand teaching and research capabilities. Internally, many graduate programs have increased emphasis on economic theory and quantitative methods, perhaps at the expense of more general applied research methodology, history, and institutions. We still do not do well in exposing graduate students to noneconomic views of phenomena considered by economists or giving them perspectives about fitting economics and economic and social problems into space, time, and philosophical context (Castle). The once-held view that there is too much agriculture and too little economics in agricultural economics is undoubtedly less true today.

Agendas call for increased interdisciplinary or multidisciplinary research to shift the focus from short-run, narrowly drawn issues to longer-run, complex, and more controversial issues (Farrell). Unfortunately, such calls are likely to be thwarted by incentive systems that elevate disciplinary research over subject-matter and problem-solving research. Lack of orientation to ex-

[5] The legitimacy of expanding our scope and clientele is questionable only to the extent that we might deny access of professional inquiry to components of agriculture or those in rural areas, including the nonfarm rural population. The legitimacy issue should be of particular importance to those of us at land grant institutions.

Table 3. Subject Matter Specialization, AAEA Membership, 1956 and 1987

1956 Specializations	Percent of Total	1987 Specializations	Percent of Total
A. General Agricultural Economics	16	S810. Farm Management and Production Economics	14
B. Farm Management and Production Economics	24	S820. Agricultural Marketing	13
C. Agricultural Marketing	27	S840. Agricultural Price/Income/Policy Analysis	14
D. Agricultural Prices/H. Agricultural Policy	9	S860. Agricultural Finance	6
E. Agricultural Finance	6	S870. Natural Resources/Environmental Economics	11
F. Land and Water Economics and Conservation	8	S930. Research Methods Copy/Econometrics/Statistics	7
G. Statistics and Methodology	4	S900. Consumer Economics	2
I. Economics of Food and Nutrition	<1	S910. General Economics	5
J. Rural Sociology	<1	S830. Agribusiness Management	7
K. Foreign Agriculture	3	S850. International Agricultural Trade/Development	15
L. General Economic Theory	2	S880. Community Resource Economics	3
		S890. Human Resource Economics	1
		S940 + S950. Other Specialties	3
(C + K: Ag. Mkt'g + Foreign Ag.)	(30)	(S820 + S850: Ag. Mkt'g + Int'l Ag. Trade/Dev.)	(28)
Noncomparable to 1987 specializations	17	Noncomparable to 1957 specializations	14

Sources: 1956 *Handbook of the American Farm Economics Association* and 1987 *AAEA Handbook Directory*.
Note: Totals may not add to 100% because of rounding to nearest percent.

periment station objectives and limited and differing mixes of federal, state, and extramural funding (Johnston 1985) make it difficult to offer marginal incentives for priority research agendas, particularly those requiring multidisciplinary efforts.

Demographic changes within the profession have resulted in appointments of staff with needed technical skills but often without ready facility with the history and institutions pertinent to, what are for them, new research settings. And for some, there is minimal interest in making that investment, given the lack of institutional incentives and rewards for commitment to long-run programmatic research endeavors. For some, the lack of rewards for collaborative or multidisciplinary research also inevitably increases the disciplinary research focus. To some observers, the narrow, modern "search for academic excellence" (Bonnen 1988) is also seen as part of the demise of the tradition of applied research, possibly upsetting the sought-for research balance.

Our empirical science reputation is threatened by the paradox of increased capacity to process numerical information and a decline in availability of data on many aspects of agriculture and rural America (Castle and Hildreth, Bonnen 1988). Further, our innovativeness with respect to the development of quantitative techniques flowing from applied research has diminished (S. R. Johnson). Instead, opportunistic (S. R. Johnson) or fashionable (Debertin and Bradford) research is pursued using readily available data (sometimes with little understanding of data limitations and underlying condition) or quick adoption of "in" methodologies, in a series of unconnected short-run investigations. These pursuits meet merit and promotion criteria but often fail to meet the need for long-run programmatic research advancements of importance to decision or policy makers.

These are among the structural challenges needing our serious attention as we seek to reestablish the relevance of agricultural economics and to regain a healthy balance between theoretical and applied analysis and a willingness to cooperate with experts in neighboring disciplines, meriting the Leontief kudos of 1971.

Structural Change, Diversity, and the AAEA

It then follows that professional associations of agricultural economics are ultimately influenced by changes in agriculture and in the profession

of agricultural economics. With external change comes a continual challenge to be responsive to needs of evolving and increasingly diverse memberships. We seek to provide excellence in the services desired by current members and are concerned that we may leave significant numbers of agricultural economists outside the associations because we do not provide services that support their interests.

For the most part, services provided by the AAEA have evolved in incremental steps, attempting to reflect changing specialization and more diverse subject matter interests of the membership. They have not been of the more abrupt type requiring extensive reorganization of effort. However, the ongoing nature of structural change and diversity requires that we periodically evaluate developments and our current portfolio of services, subject to resource constraints, in order to judge whether we are adequately responsive.

Indeed, the nature of mix of association services have been subject to frequent review.[6] Periodic examination of professional associations of agricultural economics is recurrent in presidential addresses (Hildreth, Harl), in invited papers (Gessaman, Johnston 1988, Just and Rausser) and in numerous committee reports, the most recent of which is before us from the Adaptive Planning Committee. Officers and business office staff wrestle with activity and meeting elements throughout the year. The organizational structure of the association, depending on elected and appointed "volunteers" and on business office management and support services, is best suited to gradual change of the sort that has modified association activities over the past decade. In addition, goals and activities must be transparent to maintain widespread membership involvement and support.

The association is significantly different than just a decade ago. The size of our membership and the widespread desire to participate in the summer meetings have led to greater reliance on private conference facilities, transferring the logistical burden from academic departments to professional convention and business office staff. The expansion of business office capabilities is an innovation that has greatly increased our ability to offer services and monitor association activity. That capability underlies the recent confidence with which the board has approached opportunities for program expansion.

Recommendations of standing committees and board actions have transformed our annual meetings into an innovative product mix of pre- and post-conferences and workshops based on subject matter, interest group and functional activity concerns, invited addresses, invited paper sessions (some jointly sponsored), organized symposia, poster sessions, joint social and professional luncheons and dinners, and expanded selected papers and students section activities. The cafeteria of choice is awesome.

Many of our standing committees have become increasingly active in program formulation and association matters as they have moved to meet increased subject matter and functional needs of the membership. For example, the extension committee has a pre-conference, an invited paper session, three organized symposia, and luncheon activities on this year's program. Teaching and research methodology workshops are offered from time to time. The Committee on Women in Agricultural Economics has evolved to develop major preconferences on topics of significance beyond CWAE membership, becoming a resource of association-wide benefit. The Committee on Opportunities and Status of Blacks in Agricultural Economics was prominent in the celebration of the 1980 Centenary at Baton Rouge last year. Industry and international committees include sponsorship of major speakers at their banquets, in addition to session and programmatic assistance. These are but selected examples of widespread involvement in association activities. Others exist; others need cultivation.

Educational and informational publications of the association have expanded beyond the *AJAE*, by increasing the scope and frequency of the *AAEA Newsletter* and by developing *CHOICES*, a vehicle that has received wide acclaim from members and lay subscribers. The AAEA Foundation is an emerging institution with considerable promise for supporting initiatives and projects complementary to association activities. The association is represented on national activities relating to social science research, federal statistics, and agribusiness and pre-college economic education, among others. We have jointly collaborated with other associations in meeting and program arrangements. We affirm our support of regional agricultural economics associations by participating in joint membership endeavors. We have continued interest in promoting professional relations with counter-

[6] Hildreth's identification of association services include those of information, education, legitimatizing services, employment services, and social activities.

part national and regional associations, and, where such organizations do not exist, we have lent our support to assisting their development.

In short, the association has been far from static in the development of program and services. And yet, we continue to search for ways in which the services of the association can be further extended toward subject matter interest groups and functional activities, supporting the diversity of interests in agricultural economics. The question persists: How can we best recognize the diversity of membership interests and concerns?

Structural Reorganization

Structural reorganization has been discussed as one way. In this regard, Hildreth's 1977 presidential address, "The American Agricultural Economics Association: Its Prospects," articulates two strategies for the organization of the association: (*a*) to define and meet the needs of society and members within the "central" core of the profession of agricultural economics and, alternatively, (*b*) to recognize the diversity of member interests by conversion to a federated form of organization wherein the association fosters "clubs" or interest groups. Presented in a dichotomous choice framework, the either-or alternative was left for the membership to ponder, as if they were mutually exclusive.

In my view, they are not, and we are the stronger for it. Strength defined by a central core with significant and meaningful complementary activity about that core need not be incompatible. Turf disputes over core may actually have created a vacuum wherein the focus shifted to address concerns about complementary activities that better acknowledge diversity in membership interests.

The nature of past debate about a general core suggests that we may have complicated the search by narrowly focusing on subject matter specializations within agricultural economics. For example, if one were to arbitrarily regard the locus of the "farm management-production-marketing" subject-matter specializations as the historic core of the association, the observation is that the defined core has eroded, decreasing from 51% of the membership to about 27% over the past three decades. One might then either lament that the "core" has become progressively smaller over time or complain that a minority now dominates an association that represents professionals with much more widely diverse interests and concerns. Which of the two positions is taken depends on whether viewed from within or from outside the arbitrary core. Small wonder that agreement about the general core is so elusive and so divisive!

Agricultural economists in public and private employment functionally contribute to teaching, research, extension, and decision-making activities. Many are involved in combinations of the above. I suggest that, instead of defining the central core by subject matter, we might be better served by defining it as that element implicit in the definition of our subdiscipline: the "disciplinary, subject-matter, problem-solving" research underpinnings of agricultural economics.

The Research Core

Research of one sort or another contributes to all functional activities of agricultural economists. Be clear that focusing on research activity as the general core is not equivalent to espousing "research elitism." Such is not the intention nor necessarily the result. On the contrary, it places a special burden on researchers to provide not only disciplinary excellence but also relevance for applied applications useful to other professional activities—teaching, extension, and decision-making in public and private settings. By first identifying the general core, we can then proceed to work towards complementary subject matter, professional interest, and functional activities that reflect the real diversity of the membership within the profession of agricultural economics.

Research supports important elements of our teaching of undergraduates and in the education of M.S. and Ph.D. students. The empirical orientation of our subdiscipline accounts for greater emphasis on quantitative analysis and higher degrees of application than is characteristic of most disciplinary programs in economics. We relate to real-world conditions and seek to make clear the connections between theory and applications. Full-time teachers of agricultural economics are influenced by their previous training, exposing them and their students to the empirical science of agricultural economics. Even though they may not be actively involved in research, they are nevertheless rooted there.

Applied research results and the ability to structure relevant educational programs characterize the extension activity of agricultural economists. Several land grant institutions have recently sought to better integrate extension with academic programs, thereby elevating the status

and generally expanding the applied research capacities of departments. Extension programs depend on a flow, not a stock, of applied problem-solving results in order to maintain relevance to rapidly changing and increasigly diverse clienteles. Relevant applied research, whether conducted by extension economists, by departmental colleagues, or by others elsewhere in the profession, is critical to successful delivery of a timely, relevant educational program for traditional and new clientele.

Research is also of importance to decision-making activities in public agencies, in private industry, and for consultants. Decision-making activity reflects understanding gained through study and observation, either directly, making use of research results for problem solving or policy decisions, or indirectly, using skills developed from formal and informal educational programs. While their activity may not necessarily yield new research results, it does provide feedback about research needs when effective conduits are established between decision makers and researchers. The association can enhance the relevancy of both decision-making and research endeavors if it recognizes the complementarity between research capability and decision makers' needs.

Thus, the field of agricultural economics is intrinsically associated with research emanating from an empirical subject-matter-oriented science, heavily reliant on data. Unlike attempts to define the central core by a limited set of endeavors, defining it instead as disciplinary, subject-matter, problem-solving research should not lead to a reduction in membership. However, the challenge is that membership numbers may well decrease if the narrow, modern disciplinary search for academic excellence is not balanced by applied research agendas, capable of transmitting applied research results to policy and decision makers, if individuals in the association do not recognize the importance of applied research activity. It is vital to our existence as agricultural economists that we do so. Whereas previous attempts to "circle the fences" around farm firm or rural economy subject-matter definitions would have perforce excluded significant proportions of our current membership and continued diversification of membership interests, recognition of a research core for the association permits inclusion of all subject matter specializations as well as the important functions of teaching, research, extension, and decision making performed by agricultural economists.

Advancing the Association

We, thus, end with a matrix containing subject matter specializations, professional interests, and functional activities. All are related to research. We need not make the exclusive choice of core versus federation modes. Both structures are well imbedded in the association. Drawing on that strength will help us to further define and refine the nature and mix of services that will openly attract agricultural economists. Our inability to communicate our open commitment to foster the development of subject matter and functional interest groups within the existing structure chiefly impedes the continued evolution of the association in meeting the various change and diversity challenged.

Toward that goal, we need to continually evaluate the structure of annual meetings and other services, reaching for excellence with the involvement of a full spectrum of membership. Three areas of attention may assist our goal. First, we need to continue activity supporting the empirical nature of our subdiscipline. While research decisions are made at the individual and institutional level and are subject to local interests and incentives, the AAEA can continue its commitment to maintain and strengthen economic statistics supporting research pertinent to agriculture and rural areas.

Second, annual meetings have been identified as important sources for conceptual thinking (Just and Rausser). We strive to enhance the flow of information at the annual meetings and have made gradual changes in program content in recent years. We will consider further modifications to increase informational flows. Suggestions include predistribution of selected paper and organized symposia abstracts and a review of invited paper policy to better integrate functional activities and increase the exchange of ideas and perspectives by all interests and ages. Reexamination of the policy for publication of research-based invited papers may be considered. We will continue to support pre- and postconferences and will seek ways to encourage and facilitate subject matter and professional group activity in workshops and organized symposia.

Last, the association publishes four informational and educational publications—the *AAEA Newsletter*, the *AJAE*, *CHOICES*, and, less frequently, the *Handbook-Directory*. The effort to recognize our increased diversity may lead us to reconsider possibilities for expanding the flow and legitimizing the status of informational and educational articles and materials not easily dis-

tributed under the current mix and publication policies. Just and Rausser suggested that the board plays a strong role in influencing the product mix of the profession. They encouraged it to consider sponsoring publication of forward-looking problem definition and heuristic applications of economic principles as enhancements of the current product mix. Extension methodology and pedagogic materials, teaching and extension case studies, solicited essays and literature reviews, and computer-based teaching materials are among other elements for which professional interest exists, without identifiable publication possibility within the association. Enhanced possibilities for the distribution of relevant materials for subject matter and functional activity professionals within the association publication mix may confer benefits analogous to the AJAE's role for research professionals.

Concluding Comments

The theme of this address has been that significant changes in agriculture and in rural areas continue and subsequently affect the decisions of agricultural economics professionals in their research, teaching, extension, and decision-making activities. Not only has change been profound, but diversity of interests has mushroomed everywhere.

Possibilities for more abrupt and disruptive change appear likely in the impact of biotechnological innovations, in environment pressures for reduction or elimination of chemical use in agriculture, in the clamor for redefining property rights in land and water, in contentious issues among rural Americans, including those erupting in the rural-urban fringe, and in the possible consequences of fiscal pressures and mounting budget deficits, to name a few. Agricultural economists clearly have a role in increasing understanding of and resolving these issues.

There is need to rekindle interest in applied empirical analyses of responses to induced change, whether economic or political, internal or external in origin. At the margin, the profession has advanced appreciably in sector and economy analysis. One senses that our ability to evaluate the distributional impacts of change now needs some shoring up with the increased recognition of diversity about us. Bishop, in 1967, suggested that agricultural economists had then become so imbued with micro problems that they were overlooking the transformation of rural America. Now, just two decades later, the challenge might be to address some attention to the behavioral responses of heterogenous elements responding to forces of change, particularly those of the more abrupt type for which we may have relatively little understanding. That research, hopefully, will provide a needed balance of commodity, people, and resources and environment dimensions, reflecting the wide spectrum of interests and concerns in rural America.

Agricultural economics has changed in its mix of disciplinary and subject matter. Significant challenges remain to be resolved by individuals and institutions about appropriate levels of research along the paradigm mix, adjustments in educational programs, designs of incentives and reward systems to encourage applied research and multidisciplinary activities, and assurance of quality data for sought-after applied research excellence.

The American Agricultural Economics Association has a central role in facilitating and promoting continued advancement in agricultural economics knowledge for its members and for society. It, too, is not immune from the forces of change emanating from the profession, which in turn has been influenced by rampant change in rural America.

The decade of the 1980s has been one of significant development in association services. The 1990s are full of challenge. Michel Petit concluded that the diversity among the international association's membership was probably one of its greatest strengths. The same is undoubtedly true for this association. With the ongoing nature of structural change and diversity everywhere, we must—and we will—continually evaluate developments and the association's portfolio of services, subject to resource constraints, in order to judge whether we are adequately responsive to the subject matter and the functional activities of our membership.

The spirit of *Perestroika* and of *Glastnost* are everywhere. We, too, will meet the dual challenges of "restructuring" and "openness" with the fullest expectations about the rewards that it will bring to us, its members, and to those we serve.

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Agon and Ag Ec: Styles of Persuasion in Agricultural Economics

Donald N. McCloskey

It is a tradition that these addresses be given by an outsider. I speak as an outsider in praise of agricultural economics.

An outsider presuming to praise could be accused of condescension, but I assure you I come by a favorable opinion of the field honestly. I am practically an insider. Maternal relations own farms in Illinois, near Watseka. The same Roger Gray, of the Food Research Institute, whom President-Elect Johnston mentions in his paper, is my second cousin once removed. In England I have worked as an agricultural laborer. Once, in Vermont, I milked a cow. Ag econ is in my blood.

It is certainly in my brain: an economic historian had better think agriculturally, since the past was 80% agricultural. In a graduate course last spring, we spent a good deal of time discussing medieval sheep as manure spreaders, and I am finishing a book for Princeton on scattered parcels as portfolio balance in the fourteenth century. My education as an economist was much influenced by agricultural economists such as Theodore Schultz and by people working on the agricultural aspects of historical economics such as Robert Fogel. To cap it off, since 1980 I have lived in Iowa. That surely qualifies me as an expert on agriculture and its science, at any rate in the eyes of the *New York Times*.

My points of praise are four, with a moral to follow:

First, agricultural economics invented econometrics. You can look on this as a good thing or a bad thing; I consider it very good. The career of Holbrook Working alone would justify the claim, but one could mention, among others, the bevy of econometricians at Iowa State in the early 1940s, when that department was second only to Cambridge, England, among the world's collections of economics. Frederick Waugh served as president of this association in 1946 and was in the first graduating class of fellows; Mordecai Ezekiel was in the second graduating class. Marc Nerlove and Zvi Griliches cut their teeth on agricultural economics.

Second and more generally, agricultural economics takes economics seriously. When one thinks of the quintessential "applied economics," one thinks of calculations of the value of tobacco allotments or of the elasticity of demand for oleomargarine. One might claim that the perfect markets in most agricultural commodities were invitations to "believe in the market," and therefore to believe in the applicability of economics. But not everybody in agricultural economics believes in the market—Lauren Soth of the *Des Moines Register,* for example, another of your fellows and another student of T. W. Schultz, does not especially. Regardless of their ideology, agricultural economists, long before other economists, were serious enough about whatever argument was being used to put it up against the facts of the world. Economists are philosophers and engineers—certainly not the social physicists they imagine themselves to be. Agricultural economics was the first field of economics to take the engineering model seriously.

Third, agricultural economics, more than many other parts of economics, is serious about institutional details. The students of international trade, for example, hardly ever pause on their way to the blackboard to examine an institution. If economists are philosophers and engineers, they are also social historians. Most of what economists do is tell stories about the recent past, explaining why the Corn Belt went bankrupt in the early 1980s or why agricultural policy favors bigger farmers (McCloskey 1990). To do so sensibly, they need to know what they are talking about.

Fourth, agricultural economics is therefore

Invited address.

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more open to other fields than many other parts of economics. The department at Iowa State was once the Department of Economics and Sociology, harboring rural sociologists and home economists. As Vernon Ruttan argued a long time ago, the permeability of agricultural economics has been its advantage.

The moral I want to draw arrives at my strange title, "*Agon* and Ag Econ." *Agon*, as in "ant-*agon*-istic," is the Greek for "contest," as in the Olympic games. The Greeks, like American men, thought of their life in sporting terms, and so the word also meant any assembly where people meet to argue, as in a court of law or in a seminar at the academy. What is striking about the conversation of agricultural economics, viewed from the outside, and what may help to explain its success, is that it is polite—more polite than the conversation in macroeconomics, say, or even in economic history. There is amazingly little *agon* in ag econ.

You will know better than I what the reasons for this are. But, as an outsider to the field, I have a thought. I think the American and even midwestern origins of agricultural economics have something to do with it. Americans are less comfortable with *agon* than are Europeans. On this side of the Atlantic, we like to think of ourselves as getting together to raise barns and hold church picnics, achieving a common purpose by cooperating. The Civil War plays a surprisingly small part in the mythological life of Americans; and Canadians, who for this purpose share attitudes with Americans, never had a civil war. Europeans find such attitudes bizarre. Small wonder. Their civil war, which began in August of 1914, is only just coming to an end in 1990. Within Europe, other wars rage. The French since July of 1789 have not stopped fighting their revolution with each other. The recent bicentennial was an occasion for a flood of conservative reinterpretations. No wonder the Europeans, and most particularly the French, carry an antagonistic style of argument into the academy.

I would like to persuade you that this American and Canadian attitude is a good one, nothing to be ashamed of. In particular, the rhetoric of agricultural economics does not square with a European attitude toward argument. The European attitude shows up in economics in existence theorems and crucial tests of hypotheses—timeless, universal proofs using unreasonably narrow arguments. The form of argument came to prominence in the seventeenth century. Men had been killing each other in large numbers over such doctrines as transubstantiation, and it seemed therefore a good idea to discover grounds for certitude, even if narrow, that could prevent further bloodshed. Good for them. But the narrow arguments by themselves would not suffice to get you across a busy street in town. Properly, they would not change minds in the Ten-O'Clock-Club at the donut shop on Main Street. I would like to persuade you that the narrow and European styles of argument in economics should not persuade a reasonable person.

Actually, the most advanced thinkers in cognitive and computer science have grasped the point that common sense is required for thought. The computer scientist Doug Lenat, supported in Austin, Texas, by a consortium of big companies, has been trying for six years to teach a computer named Cyc the common sense necessary to handle the simplest real-world problems without human spoon feeding (Freedman). He reckons that Cyc will need 100 million pieces of information, 2 million of which have been fed in so far, with great labor. If the computer could read natural English, the learning would go much faster. But reading requires common sense, too, and in human terms Cyc is now only about four years old, too young for school.

The opposite view—that following some 3-by-5 card formula of "scientific method" is how to be a good scientist, or even a five-year old with the common sense necessary for reading, is prevalent among the normal scientists of most fields and even, I suppose, in agricultural economics. But the leading scientists do not buy into the childish hope for simplicity in life. The chemist and philosopher Michael Polanyi once characterized the 3-by-5 card notion as "voluntary imbecility." The psychologist Jerome Bruner, speaking of psychology in the late 1930s, wrote recently that, "For reasons that now seem bizarre, you *had* to convert contested issues into rat terms in order to enter the 'in' debates" (p. 29). The voluntary imbecility, this cutting off the richness of economic argument available to us if we do more than work our own little technique over and over again for the "in" debates, is slightly nutty. As we say in Iowa, it is a few bricks short of a load. The joke among psychologists these days about the narrowness of old-fashioned method is this: Two strictly behaviorist psychologists make love. One says to the other, "*You* enjoyed that. Did I?"

Neither I nor the cognitive scientists are saying that there is nothing at all in what I have called "European" styles of argument, or that to be properly North American we must become

illogical. I myself am a quantitative economic historian, and I thrill to the blackboard arguments as much as the next guy (I say "guy" advisedly, because our female colleagues in economics do not seem to get quite as much of a kick out of them). The European—one might say especially French—error is to reduce all argument to one especially simple kind, the formal proof. It is Descartes's program of the past four centuries. In its own terms it has failed. No science has in fact gotten along with the blackboard proofs that the Cartesian method holds up as the ideal.

Blackboard economics has had a long run. Like modernism in architecture, it is coming to a dead end. But economics will prosper. We in economics are going to broaden our arguments, without throwing away any of the gains from European precision.

Our official rhetoric, however, expressed in journal articles, is still pretty much stuck in a philosophy of science current in Europe around 1930.

In the August 1989 issue of the *American Journal of Agricultural Economics* there are twenty-four articles. Of these, fifteen have the standard outline of formal model followed by a serious empirical implementation, almost invariably regression analysis. Four of the twenty-four have no formal model yet engage in serious empirical inquiry (all four of these also use regression analysis). One other is a review article. Only two of the twenty-four have a formal model without any gesture at empirical implementation, and only two more have a formal model with merely illustrative implementation, directed at the new method proposed rather than a problem in the world.

The ratio of articles with serious empirical work to articles with a merely theoretical purpose is typical of the applied fields, such as labor economics or economic history. But of course the ratio is well above that in the so-called general-interest journals of economics. Wassily Leontief, a famous friend of agricultural economics, recently calculated that over half the articles in the general journals of economics and sociology were theoretical. What do you suppose the share of such articles was in comparable journals of physics or chemistry? Ten percent.

Compare the 1989 issue with the *Journal of Farm Economics* (as it was called before 1968) in 1929, sixty years before. What are the rhetorical differences between agricultural economics then and now? The ten articles in the August issue of 1929 hardly overlap at all in type with those of 1989. Only one article is a formal modeling and simulation of behavior, another (by Howard Tolley) is a piece of empirical accounting. There are five articles offering policy assessments and proposals, usually with an accounting framework. There is one outlook piece, one institutional description, and one extended appeal for more fact collecting. Only the four nonmodeling articles out of the twenty-four in 1989 look much like any of the articles sixty years before.

Most of the 1929 articles, however, use quantitative thinking. It is false to say that economics has become more quantitative over the past sixty years. Counting, after all, has been the character of economics since its beginnings in political arithmetic three centuries ago. Indeed, what is apparent in 1929 is something largely hidden in 1989, although it is there to be seen if you look hard enough: namely, that economics depends for much of its arguments on accounting. Accounting is the master metaphor of economics, determining most of its quantitative findings. It is an accounting decision, for example, to value family labor on farms at market prices. The decision alters radically how we view the efficiency of family farming.

The most striking change in method down at the practical level is of course that virtually all the empirical work in 1989 uses regression analysis. This a little peculiar when you think about it. When we as economists make policy arguments, we use accounting, as I just said, together with simulation—all the way from back-of-the-envelope calculations of elasticities to formal simulations on computers. But when we seek the facts of the world, we pretend that only the "experiments" suitable to regression analysis are appropriate. I once had a graduate student who thought that the very word "empirical" meant "regression analysis on someone else's data." Regression analysis seems to have a tighter hold on the empirical imagination in agricultural economics than it has in other applied fields, probably because of the agronomical origins of the statistics. R. A. Fisher, who named most of them, worked at an agricultural experiment station.

There are some problems with this rampant regressionitis. It means that agricultural (and other) economists do not scrutinize the other parts of their quantitative rhetoric, such as the accounting systems that force most of the results or the data collections that allow quantitative thinking in the first place. The very word *data* shows up a problem. The word means in Latin

"things given," which is the attitude of modern economists. Someone else is going to give them the facts. They would do better to think of the facts as *capta,* things to be seized and in the seizing examined closely for flaws.

And there is a quite serious, one might even say devastating, technical problem with the way economists use regression analysis, even the agricultural economists who pioneered its use in social science. Every one the twenty-one articles that use regression analysis in the 1989 issue of the *Journal* grossly misuse it. They take statistical significance to be the same thing as scientific significance. Professional statisticians have understood since, at the latest, 1919 that the two have little to do with each other. That a coefficient is statistically significantly different from zero says merely that a sampling problem has been solved. Some scientific problems are sampling problems, but most are not. Most are problems of how large is large. We decide as economic scientists whether a coefficient is large for our purposes; we cannot hand the task over to a table of Students-*t*. Some day, in other words, all the econometric work in the 1989 issue will have to be done over again because it depends on this confusion. Have you ever wondered why regression analysis in economics never seems to settle an issue as decisively as its rhetoric would lead you to expect? Here is why: statistical significance has almost nothing to do with scientific significance (see Boring; Neyman and Pearson, p. 296; Wald, p. 302; Arrow; Griliches; Freedman, Pisani, and Purves, pp. 501, A-23, and throughout; Kruskal; Leamer; McCloskey 1985; Denton).

The regression analysis, though, as much as agricultural economists love, honor, and obey it, is merely a detail of method. A deeper content analysis of the articles in 1929 and 1989 would show them to be more similar than my listing of nonoverlapping types suggests. Agricultural economics is still concerned at bottom with how farmers behave and whether their behavior is good for them or for anybody else.

Yet, the rhetorical spirit of the articles definitely changed in sixty years. The big change is the rise of Cartesianism. That is to say, the big difference between 1929 and 1989 is, oddly, philosophical. The push for "testable hypotheses" is palpable. Just below the surface in 1989 lies a commitment to a bankrupt model of scientific method. We economists all think that what we do is similar to what physicists do. Actually, we know next to nothing about how physics operates as a field. An article in the magazine *Science* in the fall of 1989 told how the physicists at the new Santa Fe Institute are amazed at what the economists there consider to be science. The economists, who are mainly theorists, think that science involves mathematical proofs of the theories and then the equivalent of econometric tests. In truth, the physicists could care less about mathematical proofs; even the theoreticians in physics spend most of their time reading the physical equivalent of agricultural economists or economic historians. Milton Friedman's famous article of 1953 on positive economics is most of what we economists know about philosophy of science, which we think prevails in physics. The more venturesome have acquired their erroneous 3-by-5 cards from somewhat fancier sources, such as Karl Popper or Thomas Kuhn (hastily read if read at all).

The methodological thinking of economists is a scandal. It is surprising that economists, who say that they admire physicists and philosophers of science so much, do not know what is going on in these fields. The narrow philosophy of science that underlies most of the articles in the *American Journal of Agricultural Economics* and its sister journals in other fields has been exploded for decades. The history and sociology of science have shown again and again that no scientist has followed it—that Pasteur, for example, kept double laboratory books and that Darwin had his theory before he examined the facts. An economics that really imitated physics would look a lot more like agricultural economics than like the latest formalism in the *Journal of Economic Theory*.

How have we gotten so far off base? Why has economics, and even agricultural economics, failed to hear the most elementary message from statistics or physics or the philosophy of science? Well, the same way we got to be so smart at what we do: by specialization.

You will hear from deans—I hear it from some of my own—the argument that what we need is more specialization, "building on strength." We are to be shoemakers sticking to our lasts. We are to build strong walls around disciplines, failing to emulate the breadth of learning in the older generation of agricultural economists or labor economists or economic historians.

Superspecialization in academic life is not natural or productive. It is caused by an administrative decision in favor of the invisible college, the college of one's narrow subspeciality. The faculty of the invisible college have become the only voters on tenure and salary. Outside opinions in letters of recommendation count for

more than the opinion of colleagues down the hall. With a changed audience, naturally, the written products and the policy thinking of the superspecialized fields have changed. The audience for most agricultural economics is not even other agricultural economists, not to speak of policy makers or (perish the thought) actual farmers. It is the handful of other specialists, for the purpose of their specialization and no other.

An anonymous respondent to a survey put his finger on what drives the character of academic journals now even in agricultural economics: the societies and their journals "have become agents to establish professional credentials for tenure, promotion or a job offer" (quoted in Just and Rausser, p. 1189). As Just and Rausser argue, "Many of our recent graduates spend most of their time wondering about the application they can make of standardized solution frameworks rather than finding interesting problems that require the development of customized frameworks" (p. 1179). That is how you get tenure when the visible college gives way to the invisible one.

The superspecialization in economics is not justified by results. If you think it is, tell me, please, what economics has learned since the War from the more spectacular superspecializations. No fair claiming the number of publications as what we have learned, regardless of whether they will matter to anyone in six months. I am looking for ideas that matter. We have learned more in economics from our continuing traditions of political arithmetic and economic philosophy. Human capital, the economics of law and society, historical economics, and the statistics of economic growth have come from economists who trade with the rest of the intellectual world.

The superspecialization in economics and elsewhere has been defended by an erroneous piece of economic argument. Specialization is an economic idea. But it is misused by academic planners (and even by some economists when they become academic planners) to justify high tariffs in academic life. The key economic point is this: specialization in itself is not good. In fact, Adam Smith himself (not to speak of Marx, you see) was eloquent on the damage that specialization does to the human spirit. What is good is specialization and then trade. As Adam Smith remarked famously, "Consumption is the sole end and purpose of all production; and the interest of the producer ought to be attended to, only so far as it may be necessary for promoting that of the consumer" (Smith, vol. 2, p. 179). There is no point in a feed grain farmer piling up corn and soybeans in the back yard unless he is going to sell them some day in order to consume the fruits of other people's specialization.

The trade in intellectual life is precisely the use of other people's work for one's own. It is what goes on in interdisciplinary activity, if the activity is something more than polite acknowledgment of the other's expertise, insulated carefully from disturbing one's own. If we actually read each other's work and let it affect our own, then we are well and truly following the economic model of free trade. If we do what most academics do—never crack a book outside their subdisciplines—then we are following the economic model of Albania, specializing in ox carts and moldy wheat. Modern academic life has whole fields specialized in ox carts and moldly wheat.

Understand, the argument is not against all specialization but against the failure at last to trade. It will be sweet work for one part of agricultural economics to talk long and hard about fitting translog production functions. A great many of the articles in the August 1989 issue, as it happens, centered on the translog. Maybe there is something important for economics in them. Like abstract general equilibrium and most econometric fittings, it is well worth a try. For the moment, for purposes of specialization, the researchers should stick with the figures from the Census of Agriculture and ignore what we know from agronomy or rural sociology or from the living of farm life. My argument does not attack systematic work. No one would wish to stop systematic specialization.

The problem comes when the narrow, temporary agreement hardens into a methodological doctrine for all time. Then the feed grain starts piling up unsold in the back yard and begins to get moldy. If the agricultural economists specializing in translog production functions make the temporary rule permanent, throwing everything that cannot be said in a translog function into a nonscientific outer darkness forever and ever on merely philosophical grounds, they are joining the voluntary imbeciles.

The failure of specializing modernism in psychology, economics, and elsewhere to fulfill its promises does not say it was a bad idea to try. And it certainly does not say that we should now abandon fact and logic, surface, and cube, and surrender to the Celtic curve and the irrational. We are all very glad to keep whatever we have

learned from positive economics or the running of rats or the latest identifying move in the econometrics of agricultural production functions. It says merely that we should now turn back to the work at hand equipped with the full resources of human reasoning.

The anthropologist Roy D'Andrade, writing about psychology, put it well: "One cannot expect to improve upon Freud by observing less about human beings than he did" (p. 39). We cannot expect to improve upon Smith or Keynes, or for that matter T. W. Schultz, by observing less about economies than they did. The point is economic again: we will do better with fewer arguments ruled out, with fewer arbitrary constraints on our intellectual maximization. It entails less sneering in academic life, less ignoring of chemists by physicists or of sociologists by economists or of statisticians by mathematicians or of agricultural economists by economic theorists. Considering that other scholars read different books and lead different lives, it would be economically remarkable, a violation of economic principles, if nothing could be learned from trading with them. The notion that something can be learned from trading with others merely applies consistently the economics of intellectual life. Just as differences in tastes or endowments are grounds for trade, disagreements about the causes of crime or the nature of capitalism or the causes of excess farm populations in rich countries are grounds for serious conversation.

The way to inaugurate the intellectual trade and intellectual modesty that will I hope characterize the world after modernism is to focus on rhetoric. It is an anti-epistemological epistemology that breaks down the walls between disciplines. The common ground is argument. We have discovered at Iowa that what professors have in common is not some subject or social problem but the art of argument. We have a group of over a hundred faculty in fields ranging from hydraulic engineering to late-medieval English poetry that has met a couple of hundred times winter and summer to scrutinize a professional paper by one of the group. Iowa's "Project on Rhetoric of Inquiry" has been expanding exponentially since 1980. Not epistemology or game theory or even econometrics, as much as I love them all, creates real conversations across disciplines. A focus on the rhetoric of science does, a focus on the very words of how we argue. A professor of Spanish cannot give her colleague in mathematics any advice on the substance of his paper. But she can point out to him that the form is part of the substance and can remind him that the appeals to authority so important in mathematics can be found in seventeenth-century Spanish plays. From this would come a revitalized social science, and a rehumanized one—without giving up even one of the quantitative insights from Ames or Cornell or Maryland.

The broadminded conversation in agricultural economics is a good place to begin. Agricultural economics, I say in praise, is more scientific than many parts of economics. It has a tradition of non-*agon*istic conversation that has produced thinking more important for society than the latest ruminations from the blackboard. As Johnston says, you should keep that sturdy three-legged stool for the future, ready for serious scientific milking, and with no quarreling among the legs.

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Reflections on Poverty

Clifton R. Wharton, Jr.

Most Asian cultures revere age. In Korea, for example, when you become an elder at the age of 61, there is a special birthday celebration called a "Hwan-Gap." Afterward, the entire community treats the elder as a special person. And if male, the elder gets to wear a wonderful black stovepipe top hat called a "Gac."

By coincidence, I was 61 when you named me an AAEA Fellow two years ago. So today is my first occasion to thank you for my "Hwan-Gap," and my AAEA fellowship—your symbolic conferral of my Korean top hat!

The Asian reverence for age is rooted in the idea that with age comes wisdom. But as I stand before you today, and as I look back on many years of involvement in international agricultural development, I must confess that I do not feel wise. Quite the contrary. When I compare the way I feel today with how I felt forty years ago, when my development career was just beginning, I find myself far less confident, far more troubled. Then, I was sure I had the answers—some anyway, if not all of them. Now, I have mostly questions, and some uncertainty whether even those are the ones we really ought to be asking.

The Persistence of Poverty

From the beginning, the central target of my commitment to international agricultural development has been poverty in the Third World.

In the early days of development assistance, so many of us thought we knew the recipe for sound, self-sustaining economic growth in what we then called the underdeveloped world. From a peck of idealism, a pound of politics, and a pinch of hubris, we stirred into being a whole alphabet soup of technical assistance agencies. The U.S. government, private foundations, voluntary organizations, the United Nations and its associated ventures—all joined in the effort. What a marvelous brew! Or, to mix metaphors, what a splendid quest! King Arthur's knights had nothing on us. Ours too was a Holy Grail: the economic salvation of our less fortunate fellows by banishing the scourge of poverty from the earth once and for all.

I exaggerate a little, but only to make a point. We were all so confident . . . so committed. There was no doubting the justice, even the nobility of our ends. How therefore could we doubt that we would find means to achieve them?

But as I look back, I see at best mixed results to redeem all that confidence.

The aggregates do show progress in income and consumption for the developing nations as a whole (World Bank). Life expectancy is up; child mortality is down.

We also have our success stories. There are several "newly industrialized" nations—Korea, Taiwan, Singapore—with levels of affluence barely imaginable at the end of World War II.

But the more arresting fact is still that of obdurate, endemic poverty. Despite the success stories, there are other horror stories: in the Caribbean, in Latin America, especially in sub-Saharan Africa. The World Development Report 1990 estimates that there are more than one billion people in the developing world in poverty.

Why?

In the United States, real per capita income has reached levels no one would have dared predict forty years ago. Yet even here, poverty seems more, rather than less, entrenched, not only in the rural regions like Appalachia but also in the centers of virtually all our greatest cities. Instead of "exporting" affluence from the West, it is almost as if we have spent the last four decades gradually "importing" poverty from the Third World. And, indeed, when you walk through the South Bronx or North Philadelphia or Watts, California, or downtown Detroit, the sounds and images often seem not those suitable to the most prosperous nation in the world but disturbingly like what you saw forty years ago on the streets of Calcutta, Djakarta, and Port-au-Prince.

Why?

Despite the resources we have poured in over

Fellows address.

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nearly half a century, poverty remains in many sectors of the Third World. Here in the United States, too, poverty seems to have extended rather than pulled back its reach. You may be tempted to object that this is more a matter of greater visibility, via daily newspapers and broadcast news, rather than greater reality. Yet, data suggests that "since the mid-1960s at least (and ignoring the growth of in-kind transfers), there has been little progress in reducing the incidence of poverty among the [U.S.] population as a whole" (Sawhill). And in the United States, if not abroad, there is even reason to suspect that the individual experience of poverty for the poorest of the poor has gotten worse rather than better—more grinding, pernicious, and inescapable today than a generation ago.

Why?

Why is poverty so persistent? Why, despite all our efforts and resources, are we still struggling with poverty?

The Faces of Poverty

Economic development is a process. Poverty is a condition. Hence, the existence of poverty does not necessarily mean the absence of economic development. Development concentrates on a whole range of economic, social, cultural, and political variables. Deficiencies in some or all of them may account for the presence of poverty. But more and more, it appears that addressing them is no guarantee that poverty is going to go away.

What I find particularly striking is the changing relationship between domestic poverty and world poverty. The war on international poverty dates essentially from President Truman's "Point Four" in his 1949 inaugural address. The war on domestic poverty dates from President Johnson in the mid-1960s.

As I look back over the literature, I am struck by three aspects.

First, because most of the Third World nations were predominantly agricultural, the early attack on their poverty was concentrated in the rural areas. As a proportion of population, poverty usually afflicted the majority in these nations. In the late 1940s and early 1950s, the conventional wisdom was that two-thirds of humankind in these countries lived in poverty. They were rural and depended upon agriculture. In the 1950s, many of these nations began to experience massive rural-to-urban migrations which dramatically escalated their urban poverty, and the massiveness and pervasiveness of poverty persisted.

In the United States, on the other hand, poverty in the 1940s was heavily rural, and somewhat urban, but not nearly as massive a proportion of the total population as in the Third World. Urban poverty tended to concentrate among recent immigrants and distinct ethnic groups. In the rural deep South, poverty was overwhelmingly black; in Appalachia, white. Whether urban or rural, U.S. poverty was mostly that of the "working poor"—though during the great Depression half a generation before, unemloyment and rootlessness had played a much more prominent part.

Second, the disciplines which devoted attention to these issues tended also to be different. Agricultural economists, rural sociologists, and cultural anthropologists predominated in studying and acting upon foreign development. In the United States, the same groups were involved on the rural side of the equation, but general economists and sociologists dominated the dialogue on the macro and urban dimensions of poverty.

A third change has been in the differing perceptions of the nature of poverty between the United States and the Third World. Just as the faces of poverty differed in the late 1940s between the United States and the Third world, so did prescriptions for change. In the United States, with all its abundance, poverty appeared as an institutional rather than a resource issue, thus susceptible to amelioration through political change. There was an implicit assumption, sometimes quite contrary to the explicit rhetoric, that U.S. poverty was an aberrant thing, a weak countercurrent to the general prosperity.

Slowly, however, it began to dawn on the experts that poverty was not simply an anomaly. The wide range of programs that made up President Lyndon Johnson's "Great Society," principally the Office of Economic Opportunity, was the first explicit public acknowledgement that poverty in America was serious and deep-seated. Still, the problem was seen as basically correctable with the proper mix of programs and dollars.

In most of the Third World, by contrast, poverty seemed from the outside as much more fundamental, a by-product of population growth in collision with scarce resources, pre-industrial technologies, and institutions and value systems incompatible with the requirements of scientific

and material progress. We who were entering development following the end of World War II saw eliminating poverty in the less-developed countries (LDCs) essentially as one of the challenges of "modernizing" traditional societies. As in the United States, that meant political and institutional change, but it was not the kind of reformist, incremental change familiar in the United States. There were frequent discussions as to the feasibility of jumping over entire stages of national development: from feudalism directly to capitalism, from peasant agriculture to centrally planned industrialism.

Over the years, development efforts in the Third World concentrated on a whole range of economic, social, cultural, and political variables. The belief was that deficiency in some or all of them accounted for the presence of poverty.

There have been endless differences of approach.

Initially, basic western science and adapted technology transfer would be the key to everything. Next, we had the debate between free markets and socialism and state enterprise as the true path to economic nirvana. Then we talked a great deal about agricultural and industrial infrastructure, roads, rural and urban health care delivery systems, mass literacy, and educational elites. But what we often seemed to have in mind was a naive wholesale reinvention of entire societies, in the image of our own.

Next, there were approaches focusing on stimulating self-sustained economic growth as the key to eliminating poverty. Others pursued "microdevelopment," a single project, program, or bundle of efforts that would trigger systematic change. Extension, cooperatives, village-based development, supervised credit, all these and more had their advocates. Some looked for a magic potion, an innovation or technology—remember the early days of the "Green Revolution"? (Wharton 1969a). Some searched for a model to provide broad-based reform. Still others looked for the variables responsible for general economic growth, hoping for the "rising tide" that lifts all boats.

The evidence is clear that general economic growth has helped to reduce the incidence of poverty. This is particularly true if there are policies and programs which concentrate on making maximally productive the labor resource of the poor and if the poor are also provided with social services such as education, health care, and improved nutrition. Where this course has been followed, there has been success. This is especially true if coupled with a solid policy pro agriculture and pro role of the rural labor force.

But despite all the advances based on these approaches, the sad fact is that development has, more often than not, fallen well short of its goal of eliminating poverty in the Third World. My professional colleague, Woods Thomas, Dean of International Programs at Purdue University, has offered some thoughtful observations on what has been behind the shortcomings of development assistance projects in meeting the poverty challenge. Overall, he suggests:

- We haven't been able to provide the magnitude of resources needed, on a sustained basis, to make a difference.
- We have seriously underestimated the time required for development to work and to have a substantial impact on poverty.
- We have underestimated the difficulty external donors have had in "staying the course," and at times we overestimated their commitment to doing so.
- Changing sets of "interventions" have disrupted the development process, too often following short-lived "fads"—from technology transfer, to institutional transfer, to capital transfer, to international welfare, to environmental issues.
- Multiple development objectives—from international humanitarianism to economic self-interest to national security—have collided, often muddling the aim and undercutting the effectiveness of programs. —Wharton 1983

So the fact is that development has not always lived up to its hopes. And even when we see significant overall economic development in a nation or region, we also see that it often leaves stubborn pockets of poverty untouched. As a result, both advanced industrial nations and our "newly industrialized" successes still suffer the blight of enduring poverty—severe want in the midst of plenty, the dry rot of deprivation weakening the joists, joints, and rafters of abundance.

To account for this, some resort to biblical fatalism: "Ye have the poor always with you." True enough, if by "the poor" you mean those in the bottom 25% or 30% of a normal frequency distribution of income. Some will always have less than others. But this is an entirely inadequate, as well as heartless, way of looking at the problem.

We economists love to argue the merits of absolute versus relative measures of poverty and the degrees of inequality in the distribution of income. We can debate with considerable eru-

dition the view that a relative measure based upon a percentage of median income is preferable to a poverty threshold of basic needs adjusted for inflation. I will fully admit that the conceptual definition of poverty is important to understanding its scope and certain analyses of its dimensions. However, after all is said and done, I am still left with my question.

Why do we still have poverty?

If we shift once again to the United States and domestic poverty, the question is equally valid. Regardless of the definition used, absolute or relative, poverty declined for about twenty years and came to a halt after 1970, with estimates ranging from 6% to 18%. Why, in a nation and indeed a world of vast wealth and resources, poverty need exist at all? To be sure, some will perhaps always have more, while some have less. But what makes it inevitable that some must have virtually nothing at all?

The idea of a poverty threshold, a minimum below which no person can or at least should have to live, has wide political acceptance (or at least acquiescence) and currently underlies much of the U.S. welfare philosophy. Nevertheless, U.S. poverty seems to be getting worse both objectively, in the number of people "below the line," and subjectively, as a result of the growing exposure of the poor to the pathologies of ever more virulent crime, substance abuse, mental illness, and other forms of marginality.

And once again, the question is: Why?

Third World Poverty: A Taxonomic Overview

The recent history of international development—the years from 1960, say, to the present—has been in part the history of our growing understanding of its limits, complexities, and obstacles.

At the same time, we have learned to look at Third World poverty not simply as innate to "traditional," "pre-industrial" economies but as the result of conditions and forces that vary tremendously from setting to setting. Indeed, theoretical work now combines with a rich archive of field studies to offer a taxonomy or framework of such forces. And it may be helpful to mention here several of the ones that I believe have the most to tell us, not only about why poverty exists in particular areas, but also about why it has been so frustratingly difficult to eradicate.

Climate, Topography, and Natural Resources

An area's climate, topography, and natural resources form the substructure, if you will, for its economics. Absent offsetting forces, moist and temperate grasslands will probably see greater development than arid deserts or frozen tundras. Plentiful waterways irrigate potential cropland and provide natural trade routes; impassable mountain ranges impede movement and commerce, though they may also offer valuable security against hostile incursions from outside.

This is by no means to say that geography and natural resources are always overwhelming influences. But in many ways they are the bedrock upon which agriculture and the intervening factors rest. Other things being equal, the natural a priori can be the key to whether a society will thrive or struggle.

How much of the residual persistent poverty that we see in the Third World is the result of these factors?

History, Mores, and Socioeconomy

Following the natural environment, the next basic set of factors are those of an area's history, mores, and structural socioeconomy. The realities of the past often decide the possibilities of the present—a truth which in our earliest debates we sometimes considered the unbreakable "cake of custom." Later we came to modify that, concentrating on those leverage points that might hasten the transformation of tradition-based societies into modern ones (Wharton 1969b).

Likewise, the large structural features of an area's socioeconomy are always important. Population size, age distribution, geographic concentrations, and many related demographic factors correlate either positively or negatively with poverty. Most significant in the Third World has been the impact of the food/population equation coupled with the human/natural resource ratios. And of course it is foolhardy to look at any of these in isolation from mores: the pervasive strictures of behavior that may, over time, institutionalize poverty within the tangled webs of class and custom.

Values and Attitudes

In the early literature of economic development, there was a kind of caricature: the culture-bound, tradition-ridden, religiously channeled peasant

or villager, whose unwillingness to adopt or even tolerate modern ideas is the rock upon which otherwise viable efforts inevitably breaks up. Or, to put it more positively: the traditional figure whose rigid values and attitudes must be comprehended and somehow accommodated if development projects are to have a realistic chance of success. This inaccurate image gradually changed in recognition of the true underlying factors producing resistance.

Nevertheless, we did conclude that there are individual values and attitudes that are especially relevant for the elimination of poverty which are considered to be favorable toward self-improvement and pro development. These range from high achievement orientation and strong self image to high propensity to save/invest and the work ethic.

Some questions:

What are the aspirations of the permanent underclass, and how do they differ from the working poor? The rest of society? Which components in their "aspirational bundle" are subject to manipulation to stimulate a positive change and movement out of poverty? Which ones are significant from a policy and operational standpoint?

To what extent have programs of aid to raise levels of living above the poverty line created a new subculture of dependency where aspirations for further progress have been eliminated?

Political Will and Commitment

The role of the political process and political leadership in the attack on poverty is of central importance. This is true regardless of the form of political structure—democratic, oligarchic, dictatorship, etc.

Several years ago (1976) I pointed out that there are two political requirements for achieving significant sustained agricultural development: first, that the political leadership have a genuine commitment to the goal of agricultural development; and second, that they have an understanding of the process.

As is true in most politics, there are significant trade-offs between conflicting political goals in any attack on poverty. These are both internal within a nation and international among nations. For example, how the political leadership resolves the choices between greater governmental investments in the education of the rural poor versus improved urban transportation, or the choice between subsidized prices for domestic food grains versus imported food can have a dramatic impact on the success or failure of any attack on poverty.

Above all, there must be a political will and commitment to eliminate poverty if there is to be any likelihood of success. Those nations which have been the most successful in reducing the scourge of poverty have inevitably been those which have displayed a commitment to its elimination and the will to carry it out.

Given our understanding of development, despite its imperfections, how much of hard core or residual poverty is the result of a lack of political will for its elimination?

Knowledge, Education, and Human Capital

Finally—and, in my view, perhaps most important—there are the knowledge, education, and human capital available to a society. The centrality of human capital to economic development is documented in the literature of economic development, most brilliantly in the seminal work of Nobel Prize winner Theodore Schultz. In the present context, I would only note that the insufficiency of human capital—the lack of what I might call a "critical mass" of knowledge, skills, and collective educational attainment—seems almost universally implicated in truly persistent poverty. Indeed, when it is a case of the kind of intractable poverty that over time stymies both spontaneous growth and organized development efforts from within or without, human capital problems will almost always be found to be critical.

In my experience, to put it bluntly, it seems almost impossible for societies to be both smart and poor for very long. So even in a taxonomy that stresses variability, overdetermination, and multiple causation, I would stress the particular sensitivity of human capital as a kind of privileged factor among the many others.

The Convergence of U.S. Domestic and World Poverty

Admittedly, creating a taxonomy does not necessarily take us very far. Indeed, taxonomies and surveys often seem to raise more questions than they answer. For example, in a comprehensive survey of the empirical literature, Sawhill tested the efficacy of five key variables for explaining the persistence of poverty in the United States

from the 1960s through the mid-1980s. And her findings are instructive:

One, she found that demographic change is a good explanatory variable in the growth or reduction of poverty, but "virtually all of the effect is due to the growth of households headed by women with children"—an important segment of the domestic poor, but by no means the only one.

Second, the performance of the economy also is an explanatory variable in poverty reduction, especially among the non-aged. Even so, Sawhill found that "other variables have been operating to offset the effects of growth."

Human capital investment, though slightly positive, seems to have mixed results, to the point where "both the skeptic and the true believer can find support for their positions."

Behavioral and value change resulting from income transfers becomes an imponderable. It can be shown that income transfers themselves, more or less by definition, can reduce poverty. But does that create a "feedback" mechanism, creating more poverty by inculcating a psychic and behavioral "culture of dependency"? The explanation founders on the difficulty of establishing a causal connection between the income transfers themselves and the attitudes and behaviors supposedly fostered.

The growth of an "underclass" is definitely taking place, even though it is still a smaller fraction of the total poor population. More basically, to explain the persistence of poverty by pointing to the underclass is to try to make the question its own answer. It is profoundly unsatisfying to argue that the reason poverty persists is that we have a group of people who are acutely poor.

At the end, therefore, of Sawhill's exhaustive and thoughtful analysis, where do we come out? "Until more complete theories and models . . . are developed and tested, the answers to some of the questions raised in this article must remain partial and tentative."

So, here in the United States as in so many nations of the Third World, we find ourselves still without any really satisfactory understanding of why poverty persists.

Most striking is the growing convergence between U.S. domestic poverty and world poverty such that we appear to be moving to a situation where there are certain nations, areas, and groups which can be characterized as hard core, persistent poverty. Moreover, the most salient characteristic of domestic and world poverty is that it does persist; that it seems so endlessly resilient, so capable of thwarting our most ingenious efforts to eradicate it. And both here and in the Third World, we see more and more a kind of "poverty within poverty"—whether the "poorest of the poor" or the "urban underclass"—that forms a hard, self-sustaining core not only of indigence, but also of crime, substance abuse, illegitimacy, illiteracy, and other pathologies.

Persistence and hard-core pathologies appear basic, thus, to both domestic and Third world poverty. And this raises questions about possible other similarities and etiologies: What links are there between the "culture of despair" in Harlem, New York, and in a hillside favela in Rio de Janeiro? Are the self-reinforcing negative factors of poverty living levels—disease, ill-health, dependency, illiteracy, crime, unemployment, alcoholism, drugs—the same? Why is it that poverty afflicts disproportionately women, ethnic groups, minorities, and indigenous people, a pattern that is world-wide and growing? (In this regard, I commend to you the invited paper for this conference by Ralph Christy and Enrique Figeroa.) Is there something fundamentally different in hard core poverty from other forms of poverty?

A Two-tier Nation in a Two-tier World?

When I entered international agricultural development some four decades ago, the popular view was that ours was becoming a "two-tier" world, with potentially explosive consequences. The first tier was the 5% of the world's population, contained almost exclusively in the industrial West, that controlled 80% to 90% of the world's wealth. The second tier was "everybody else"—poor, hungry, nonindustrial, often postcolonial countries in Africa, Asia, and Latin America.

Forty years later, we still have a world of at least two tiers.

Yes, there has been development in the Third World. The recent World Bank report, *Poverty,* cites dramatic examples of nations where both economic and social indicators establish that growth and improvement in well-being have occurred. But the bank also reports that over one billion people have less than $370 per year and are still living in poverty, with the heaviest concentration in South Asia, East Asia, and sub-Saharan Africa. And while they project a decline in the poor in most regions by the year

2000, they also predict an alarming increase in poverty in sub-Saharan Africa to about a quarter billion!

Given the commitment, hard work, and resources that have gone toward development throughout the period, I come back to my original question.

Why?

Here in the United States, we seem on the verge of becoming a "two-tier" nation. Here too, the gap between the top and the bottom appears to be growing: "[Income] inequality has been growing within almost all demographic groups and occupational and industrial sectors, and it has been growing during recoveries as well as during recessions" (Sawhill). Even today, most poverty in the United States, including black poverty, is not the poverty of urban slums. Yet, winding down from a domestic economic boom that has been the most sustained since the end of World War II, we seem at a loss even to slow, much less reverse, the growth within our cities of permanent enclaves of hard-core poverty. And that poverty is rapidly becoming as intractable and debilitating as I have seen anywhere in the world.

Why?

I do not have the answer.

I am not even sure any more that we have the right questions.

And that is deeply discouraging, in and of itself. On the international side, after forty years of organized technical assistance and development aid, should we not have at least a better understanding of what the key causes of poverty are and, more important, their cures?

We know a great deal more about achieving development than we do about eliminating poverty.

After pouring millions of hours and billions of dollars into projects in scores if not hundreds of impoverished communities, would you not expect that we would have reached some broad consensus on how to break the cycle of poverty? Should we have developed a general theory or model? Or is it that hard core poverty is too difficult to attract the creative energies of our best minds?

And when it comes to domestic poverty, can we really not ask many of the same questions? After a decade of the Great Society, followed hard on by another decade of the Reagan Revolution, you certainly cannot say that we have not tried a broad spectrum of approaches. We have bounced from scattershot activism, to benign neglect, to the trickle-down theories President Bush once, in another life, called "voodoo economics." Should we not at least have a better sense of what is likely to work and where and under what conditions?

Why do we not?

Again: I do not know.

I do know that we have reached a stage where there is a far greater degree of universality to the faces of poverty both in the advanced nations and the Third World. We in the United States can no longer adhere to our peculiar idea that poverty here—the United States—is different from poverty there—elsewhere in the world.

In the early days of international development, as I have said, we Westerners thought we knew the solutions to their, the Third World's, problems. Over the last forty years, we have learned to our chagrin that we did not have all the solutions, after all. And in the last ten or fifteen years, we have found our problems looking increasingly like "their" problems, to the point where it has become a cliché to compare the urban terrain of the United States to the impoverished nations of the Third World.

Beyond the cliché there is an underlying reality, the reality of interdependence and globalization in our problems and their resolution. Nowhere is this more critical than the problem of the persistence of poverty. The universality of the challenge of persistent poverty may be the true test of our true faith in the age-old sense of "one world." Economic development abroad and economic revitalization at home are shared problems because they are the challenges of our shared future, our common destiny on a shrinking planet.

Conclusion

In the preceding discussion, I have asked a lot of questions. And I have freely admitted that I cannot answer them, even after an adult lifetime in which development has been an abiding professional and personal interest.

The final question I must ask myself, then, is whether there is room for optimism or whether we are doomed to failure. And that is a question I can answer: we must continue to seek the solutions that will reduce the incidence of hard-core poverty at home and abroad. To do less imperils not only the economic security of the world but, more important, the very lives of

millions upon millions of men, women, and children.

I hope I have been able to convey that, despite our frustration and mistakes, we have learned much over the years. Our task now is to take what we have learned, analyze it, and reapply the knowledge in a manner that avoids those past errors and strikes at the heart of the problem.

We now know that the job will take much longer than we once brashly thought. We know that gimmicks will not work. We know that the external resources required are much greater than we once believed. We know that the multiplicity of objectives driving development assistance are counterproductive. We know that the attack on poverty requires the political will and a sustained commitment. And we know that, if past breakthroughs are valid measures, solutions will take our most creative minds.

But these are challenges, not insurmountable obstacles. So I ask you, then, to join in a rededication, a rededication to a sense of confidence that we can win this battle against poverty, that we must win it, that we will win it.

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Analyzing the Farm-Level Impact of Agricultural Credit (Richard L. Meyer, Ohio State University, presiding)

Rural Credit and the Mix between Permanent and Temporary Wage Labor Contracts in Pernambuco, Brazil

Julie Anderson

During the last three decades, urban-based temporary agricultural workers have grown in number and visibility throughout Brazil, provoking research into the forces that drive shifts in agricultural wage labor demand away from "permanent" (year-round) toward "temporary" (daily, weekly, or harvest season) arrangements (see UNESP). The mix between permanent and temporary employment is of great concern in the sugarcane-producing coastal zone of Pernambuco, where both temporary and permanent employees find steady work cutting cane during the four- to six-month harvest season, but only permanent employees have steady work during the rest of the year. Temporary workers released from agriculture during the slack season find little nonagricultural employment, so their incomes drop sharply; and such seasonal reductions in income are considered especially deleterious to the welfare of workers who have little ability to smooth consumption through borrowing.

Increased seasonality in agricultural employment, which takes the form of a reduction in permanent employment as a share of total harvest season employment, may generate broader social costs as well, by inducing seasonal increases in theft, prostitution, and urban unrest, and increased seasonal migration of household heads away from their families. Thus, inferences about the effects of agricultural developments on the welfare of both the rural poor and small town dwellers require examination of changes in the mix between permanent and temporary agricultural employment, as well as changes in total peak season employment and wage levels.

A study of agricultural wage labor markets in Pernambuco (Anderson) showed that an absolute and relative decline in permanent employment during the 1960s resulted largely from the introduction of severance pay legislation for rural labor. The legislation increased the relative cost of labor hired under permanent contracts and changed the nature of the permanent labor institution by eliminating employers' ability to use the threat of dismissal as inducement for permanent employee "subjection." In the 1970s the volume of temporary employment continued to grow. Permanent employment grew even faster, however, because as labor markets grew tighter, permanent contracts became increasingly attractive as means for guaranteeing the availability of harvest season labor. Despite the continuation of these forces into the mid-1980s, the ratio of permanent employment to total harvest season employment failed to increase, and even appears to have declined.

This paper argues that the great increase in interest rates on rural credit in the 1980s significantly reduced farmers' incentive to employ workers on a year-round basis, and in fact explains the relative decline in permanent employment during the period. The conceptual framework for the argument is described in the second section, and a more formal discussion of the model may be found in an appendix available from the author. The model incorporates economic rationales for the observation that slack season labor is hired under permanent contracts,

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while harvest season labor requirements are filled by a mix of permanent and temporary employees. The model combines these institutional considerations with a detailed depiction of the technological possibilities constraining farmers' production and employment decisions in this region, identifies the range of exogenous factors that might induce changes in the equilibrium permanent employment share, and predicts the signs of their effects. An increase in the interest rate on short-term credit should increase the finance charge-inclusive cost of slack season labor and induce a reduction in the permanent employment share.

The central empirical argument for the importance of the interest rate effect is found in the third section, which describes changing economic circumstances in Pernambuco during the early- and mid-1980s, showing that, of all the determinants of rural labor market structure, only the interest rate changed in the direction predicted to reduce the permanent employment share. Many other changes were taking place, but all of them would be predicted to increase the permanent employment share. Thus, the interest rate effect must have been strong enough to counteract tendencies toward increased permanence and induce the observed decline. As discussed in the fourth section, econometric analysis of 1988–89 cross-section data corroborates several elements of the argument and, thus, is useful even though it allows for no direct estimate of the interest rate effect.

Determinants of the Mix between Permanent and Temporary Employment

Permanent agricultural workers in the region under consideration are those contracted to work year round, planting and weeding sugarcane during the interharvest season and cutting cane alongside temporary workers during the four- to six-month harvest season. Employers retain slack season workers under two-season or "permanent" contracts, thus securing their harvest labor in advance, since by so doing they may reduce labor costs in at least two ways. First, they avoid the high costs of having to recruit labor during the peak season (Bardhan 1979), which include both direct search and transport costs and the losses that occur when labor shortages prevent a sequence of agricultural tasks from being completed in a timely fashion. Second, if workers have no access to credit or insurance markets, then the discounted, expected cost of employing them for two seasons may be reduced by smoothing their wages across seasons and across states of nature. Thus, permanent contracts implicitly providing consumption credit and insurance may allow payment of harvest season wages that on average are lower than spot market wages (Bardhan 1983).[1]

The harvest cost savings associated with permanent contracts suggest that all slack season workers will be retained under permanent contracts, and that slack season labor will be hired beyond the point at which its marginal product equals its wage. Whether the cost savings stimulate farmers to offer year-round employment to many or few of their workers, however, depends on technological substitution possibilities and on the full configuration of prices and fixed factors conditioning production decisions.[2]

Farmers in this region have several technical options for varying the ratio of slack to peak season employment, while maintaining the volume of output. Semimechanization of the harvest—in which mechanical harvesters pick up loose, manually cut cane and load it into trucks—reduces harvest labor demand by making the bundling of cane unnecessary; so it allows increases in the permanent employment share. Herbicide use, on the other hand, reduces slack season labor requirements. Further, farmers may vary the relative importance of "extensive" and "intensive" cultivation practices. Extensive practices involve minimal replanting and weeding and consequent low productivity per acre, while more intensive practices involve replanting a greater proportion of the cane each year and weeding the standing cane several times, increasing per-acre slack season labor requirements. Though more intensive cultivation increases output, it also renders cane easier to cut, and seems to increase harvest labor requirements by less than slack season requirements.[3]

The ratio of slack to peak season labor re-

[1] Two other rationales for the existence of permanent contracts, related to incentives for unsupervised labor and to cost reduction through in-kind payments, are of historical but not current relevance here (see appendix).

[2] The properties of the region's sugarcane technology described in the following paragraphs should be regarded as assumptions underlying the proposition of the paper; they are based on casual observation and preliminary analysis of cross-section data, but they merit closer empirical examination.

[3] Fertilizer is applied in uniform per-acre quantities to most sugarcane land in this region. In a few cases, some of a farmer's worst sugarcane acreage is cultivated under a "very unintensive" strategy, in which no fertilizer is applied. Again, though this implies lower yields and lower harvest season labor requirements, it also implies less slack season labor use and is likely associated with lower ratios of slack to peak season labor.

quirements is also likely to rise as output expands over time on individual farms and to be greater on larger farms at any point in time. Output expansion on an individual farm requires extending either intensive or extensive practices on to land of lower quality. On steeper, poorer quality land, both slack and peak season tasks are more difficult to complete. The difficulty of slack season tasks may rise by more than the difficulty of cutting the cane, and the volume of output to be harvested also falls, making it likely that slack season per-acre labor requirements rise by more than peak season requirements. Larger farms appear more efficient in the use of labor, perhaps because of economies of scale achievable through the division of labor. The scale economies appear strongest in harvest season activities, so that the ratio of slack to peak season employment tends to rise with the scale of production.

If farmers select how much of their land to cultivate and which of these cultivation practices to employ on fields of varying quality, with the aim of maximizing end-of-year profits (while taking into account prices, wages, and the interest rate on short-term finance for slack season input payments), then the following predictions are possible. The ratio of slack to peak season labor demand, and thus the share of permanent contract offers in farmers' total labor demand, will rise when increased prices or reduced input costs stimulate expansion onto lower quality land. The permanent employment share should also rise as increases in the stock of harvest machinery reduce harvest season labor requirements, as increases in the effective price of chemical herbicides discourage their use, and as rising recruitment costs make permanent labor more attractive relative to temporary labor. An increase in the interest rate at which the slack season wage (and herbicide) bill is financed, however, will increase the finance charge-inclusive cost of slack season labor relative to the cost of peak season labor and will induce a reduction in the permanent employment share demanded.

If the net effect of exogenous changes on individual farmers' decisions is to increase total demand for harvest season labor, adjustments toward a new labor market equilibrium will provide two further reasons for the permanent employment share to rise. First, as labor markets tighten, recruitment costs rise, increasing the relative cost of temporary labor. Second, permanent wages should rise more slowly than temporary wages. If workers may be characterized as having diminishing marginal utility of income (in each season), then proportionate increases in permanent and temporary wages would produce a greater-than-proportionate increase in the utility workers derive from permanent contracts; thus, the share of workers seeking permanent employment would rise, tending to slow permanent wage growth.

The Case of Pernambuco in the Early- and Mid-1980s

Evidence of decline in the ratio of workers hired under permanent contracts to the total number of harvest season employees in the coastal zone of Pernambuco between 1978–79 and 1988–89 is derived from a farm-level sample survey administered in 1989.[4] The 1988–89 estimate of this share for the sugarcane-producing population in the sample region (based on 185 observations) is 56%. For a subsample responding to a retrospective section of the questionaires (165 farms), the share fell from 65% in 1978–79 to 57% in 1988–89. This represents a 23% increase in the share of sugarcane workers disemployed at the end of each harvest.

Several comments on the validity of the survey evidence are in order. Interviewers were identified as working with a researcher from a foreign university and were correctly perceived as having no connection with any Brazilian ministry for whom answers might be biased. Most interviews lasted from one to one-and-a-half hours, during which most interviewees were willing to provide careful answers. Some large employers had records allowing them to answer retrospective questions accurately, while smaller employers tended to be closely involved in hiring and administration and appeared to have little difficulty remembering.

The calculation of weights required for estimating both 1988–89 population shares and the sampling errors on those estimates are discussed in Anderson, where the sampling errors are found to be on the order of three percentage points. Constructing weights for the retrospective estimate required employing some ad hoc assumptions regarding land acquired and disposed of during the period by farmers in the sample, but the population estimate appears robust to vari-

[4] Average hours for both permanent and temporary workers probably fell during the period as the legal work week was shortened. Most permanent workers and many temporary workers work no more than this legal minimum, despite payment on a piece-rate basis and employers' experimentation with incentive schemes.

ation in these assumptions. The estimate also appears consistent with 1980 agricultural census calculations, which show a permanent employment share of 66% for the same group of municipalities. While some differences between census and survey shares at the municipality level suggest the margin of error is nontrivial, the conclusion that the permanent employment share declined over the period seems reasonable.

A number of economic changes over the ten-year period should have induced increases in the permanent employment share. Both area cultivated and the volume of sugarcane production experienced net expansion.[5] Though the administered price of sugarcane began to fall with respect to general price indices after 1982, the effective price of cane seemed to be rising for many growers in the region.[6] The great increase in the region's sugar refining and alcohol distilling capacity, stimulated by cheap investment finance in the 1970s, came on line in the early- and mid-1980s, generating intense competition between the mills for suppliers' cane. Farmers' certainty of selling their cane in a timely fashion increased. Some sugarmills began to offer free transport, input provision, and in some cases side payments. Expanding production brought with it rising wages and would be expected to bring an increase in the permanent employment share, as discussed above.[7]

Average non-wage benefits for temporary workers were rising relative to those for permanent workers during the period, as temporary workers increasingly sued for paid vacations, Christmas bonuses, severance pay, and other provisions of rural labor legislation, which had long been paid for most permanent workers. The expanded relevance of social security provisions for temporary workers is indicated by the observation that by 1988–89 around 40% of temporary workers were registered with the Ministry of Labor, though virtually none had been in 1978–79.

In addition, the costs of recruiting labor in the harvest season were rising. The distances employers had to go to find workers increased, and they began to provide transportation and temporary accommodations of increasing quality. Further, the timely execution of harvest season tasks increased in importance after 1983, when the price planters received for their cane began to depend on its sucrose content. This gave farmers an interest in reducing sucrose losses resulting from delays between preparatory burning and cutting or between cutting and loading for transport to the sugarmill, and thus increased the premium on having the labor of permanent employees prearranged.

The 1980s brought more mechanization of harvest tasks than did the years of cheap and abundant credit in the 1970s. The survey suggests that the share of sugarcane area harvested semimechanically rose from around 20% in 1978–79 to over 40% in 1988–89 (mostly on large farms), consistent with the observations of sector experts. Whether stimulated by rising wages and recruitment costs or by the new production of mechanical harvesters in, and appropriate for, the Northeast, this should have generated an increase in the permanent employment share.

An increase in the permanent employment share might also be expected to result from the concentration in operational landholding that occurred during the period, both through farmers (of all sizes) buying up other farms and through sugarmills reassuming direct administration of lands previously rented out. The association of larger-scale with higher permanent employment shares, discussed in the previous section, are corroborated in the cross-section results presented below.

Despite reports of increased herbicide prices relative to official daily wages, which would be expected to increase permanent employment and reduce herbicide use, a number of farmers began using herbicides during the period under study.[8] Even if the price reports are inaccurate and the relative price of herbicides declined, the decline in the permanent employment share on many farms where no herbicides were used would remain unexplained. If the relative price of herbicides rose as reported, the increase in herbicide use would appear anomalous but could in part be explained as a result of the interest rate increase. The increase in interest rates should have increased the discounted cost of slack season labor use proportionately more than it increased the discounted cost of herbicides. Fur-

[5] Hectares harvested and tons produced increased by 22% and 34%, respectively, between 1978 and 1987 (Instituto Brasileiro de Geografia e Estatística, *Produção Agrícola Municipal*).

[6] Deflated by Fundação Getulio Vargas "Index 2," the administered price fell 40% between 1981 and 1986.

[7] Average rural daily wages in Pernambuco rose at 3% per year relative to a general price index between 1976 and 1986 (Fundação Getulio Vargas).

[8] According to the records of a major producer in the region, the price of a litre of herbicide rose 182% relative to the price of a ton of cane and 110% relative to the official daily wage between 1982 and 1989.

ther, increased interest rates on credit made self-finance more attractive, at the same time that high and variable inflation may have made chemical herbicide stocks a more attractive form of saving for self-finance.

The only economic force generating a tendency for a widespread decline in the permanent employment share was the increase in the interest rate at which slack season labor was financed.[9] Through the 1970s farmers had access to increasing volumes of credit at increasingly negative real interest rates; interest rates on rural credit were fixed in nominal terms at between 12% and 18% per year, while inflation rates rose from around 20% per year in 1970 to over 75% in 1979. Rural credit interest rates began to rise in the early 1980s, though initially they remained fixed in nominal terms at 35% while inflation rose to 100% per year. Rural credit became subject to partial indexation in 1982, and to full indexation plus interest of 7% to 9% in 1987. Because rural credit was indexed to general price indices, while at the end of the period the price of sugarcane fell relative to such indices, *ex post* interest rates in units of the output became very high indeed. As late as 1988–89 a great majority of farmers represented in the sample (having at least 20 hectares) continued to borrow; and a number of those who did not use credit in that year commented that it was the first time they did not seek credit. They had received loans sized according to reasonably generous per-acre rules. Thus, the effect of rising interest rates was a widespread increase in the (shadow) cost of short-term finance. The effect on permanent employment of the resulting increase in the relative cost of permanent labor must have been strong enough to counteract the tendencies for increased permanence discussed above and induce the observed decline in the permanent employment share.

Lacking richer time-series data on permanent and temporary employment, the discussion has been confined to the analysis of net changes over a ten-year period in which developments were not uniform and could therefore be misleading. At the end of the period, farmers began to fear the elimination of sugarcane price subsidies as well as credit subsidies. Thus, for example, if the permanent employment share had risen or remained constant through much of the period, falling only at the very end, the importance of interest rate changes would be more difficult to judge. Such a scenario, in which sectoral crisis rather than sustained interest rate increases induced the change in employment structure, is implausible, however, precisely because it would require a sudden, large reduction in permanent employment. Well-enforced severance pay legislation makes such "dismissal without just cause" very costly. Comments by interviewees, and cross-section results (not presented) showing the permanent employment share to be higher on farms that experienced production declines, are consistent with permanent employment reductions being "slowed" to rates at or near the rate of attrition.

Econometric Analysis of 1988–89 Cross-Section Data

Econometric examination of the 1988–89 cross-section data corroborates some components of the above argument and thus contributes indirectly to an understanding of the relationship between interest rates and employment structure, even though it yields no direct estimate of rural credit's "farm level impact." Table I presents estimates of farm-level reduced-form equations, in which the permanent employment share is considered as a function of the technological and institutional factors varying in the sample. Approximately 10% of the sample is censored at permanent employment percentages of both zero and one hundred, so the reported coefficients are maximum likelihood "two-limit tobit" estimates.[10] Explanatory variables (including some not shown) were introduced both in absolute terms and interacted with the inverse of farm size to allow for scale differences. Interacted terms were multiplied by median farm size, so that the sum of coefficients on absolute and interacted terms yields the variable's total effect on a farm of median size. The specifications in table I restrict to zero the coefficients on variables for which the coefficients were found insignificant in unrestricted estimation.

The estimates in the first column of table I corroborate the arguments that the permanent employment share should have risen as operational landholdings were consolidated and as

[9] The discussion has focussed on labor demand side forces. It is also unlikely that supply side shifts toward temporary arrangements, such as might arise in response to increased nonagricultural short-term employment opportunities, induced the decline in permanence. Anderson cites evidence to this effect, but further research is merited.

[10] Permanent employment shares of zero arise only on small farms where family labor is important. The treatment of family labor is discussed in the appendix.

Table 1. Maximum Likelihood Two-Limit Tobit Estimates of Permanent Employment Share Equations

Variable	Specification 1	Specification 2	Mean:
Permanent employment share			46.6
Log (farm size in hectares)	6.3	6.2	5.7
	(2.1)[a]	(2.1)	
Distance to sugarmill in 10 kilometers	7.2	6.8	1.2
	(2.5)	(2.5)	
(Distance to sugarmill) *297.5/(farm size)[b]	−2.2	−2.2	3.4
	(0.6)	(0.6)	
Sample average fraction of temporary labor registered with Ministry of Labor, by region and size group	13.5	13.7	0.4
	(8.9)	(9.1)	
(Indicator equal to one if has secondary education) *297.5/(farm size)[b]	4.6	4.9	0.8
	(1.1)	(1.2)	
Age in 10 years	4.4	4.5	5.0
	(1.6)	(1.6)	
Indicator equal to one if credit taken		5.8	0.8
		(5.7)	
Constant	−22.5	−26.8	1.0
	(16.2)	(16.1)	
Estimate of standard error	26.8	26.7	
	(1.3)	(1.4)	
Number of observations	180	180	180
Loglikelihood	−724.1	−723.6	

[a] Standard errors are shown in parentheses.
[b] Median farm size is 297.5 hectares.

temporary labor recruitment costs rose. The permanent employment share rises significantly with (the log of) operational farm size, and this result is robust to reestimation within smaller farm size categories. Distance from the nearest sugarmill (usually located near an agglomeration of temporary workers) proxies for recruitment and transportation costs that increase the relative cost of temporary labor. It appears to increase the permanent employment share, though the effect is smaller for small farms. The indicator of temporary employee registration proxies for variation in nonwage temporary labor costs and is weakly associated with a higher permanent employment share. These results are consistent with the argument that recent increases in such costs should have increased the permanent employment share. They also make plausible an interest rate effect, which likewise acts through changes in slack season labor's relative cost.

Because official interest rates did not vary across farms, the interest rate effect itself cannot be estimated in a single cross section. If unobserved expectations regarding real interest rates varied somewhat across farms (despite indexation), and if farmers expecting lower real interest rates were both more likely to borrow and more likely to use more permanent labor as argued above, a positive correlation would arise between credit demand and the permanent employment share, even after controlling for variation in technological and institutional factors.[11] The second specification in the table includes an indicator of whether the farmer took out a loan (loan size reports being too noisy to be of interest), and the coefficient is found to be positive but statistically insignificant. The positive coefficient is consistent with the argument of this paper, but since a positive correlation could result from the existence of omitted variables other than the expected interest rate, even a significant correlation would constitute no proof of the interest rate effect. The correlation may fail to be significant simply because expected interest rates do not vary enough across farms, so the lack of significance allows no rejection of the interest rate effect.

Concluding Comments

Many costs of subsidized rural credit programs, such as described in Adams and Graham's general critique and in Araujo, Meyer, and Shiro-

[11] By farmers' reports, credit market participation was demand determined.

ta's discussion of the Brazilian experience, are well known; and many economists agree credit subsidies should be removed. Less has been said about the cost of adjustment to higher interest rates. This paper's analysis of historical circumstances over the early and mid-1980s in Pernambuco highlights a potential adjustment problem in regions where wage labor is important, finding that higher interest rates significantly increased the seasonality of agricultural employment. Even though such a shift in agricultural employment structure may eventually contribute to improved efficiency, it may be very costly for the most vulnerable of the rural population in the short and medium run, especially where workers released only seasonally from agriculture are not easily absorbed into nonagricultural production. The design of appropriate adjustment policies should therefore be given careful attention.

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Access to Capital and Its Impact on Agrarian Structure and Productivity in Kenya

Michael R. Carter and Keith D. Wiebe

Access to capital and its distribution across agents can profoundly shape the structure and performance of an agrarian market economy.[1] It is conceptually useful to distinguish between *ex ante* and *ex post* capital access. *Ex ante* capital access denotes the ability of agents to finance production costs (e.g., labor and purchased inputs costs) which must be paid *ex ante,* that is, prior to the actual realization of production. *Ex post* capital access, that is access to capital after the realization of the production process, is of particular importance as an insurance substitute in low income agrarian economies where contingency markets are imperfect. Buoyant *ex post* capital access would permit an individual to stabilize consumption year to year even as production fluctuates annually.

A number of theoretical models have explored the static impacts of agrarian structure and differential capital access on resource allocation and productivity (see Feder, Eswaran and Kotwal, Carter and Kalfayan.[2] In addition to empirically exploring the impact of landownership structure on productivity in capital-rationed environments, this paper explores and motivates analysis of the evolution of landownership structure itself. In the contemporary context of market-oriented agricultural development strategies in general, and land market "activation" policies in particular, it is particularly important to understand the incentives for expansion and contraction of different classes of producers.

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[1] Access to capital means access to one's own wealth as well as to the intermediated wealth and savings of others.

[2] Whether or not skewed capital access is a feature of intrinsically imperfect rural markets, or whether it reflects lender response to interest rate regulation, is an important question of considerable importance and debate in the literature (see Adams and Graham, Carter).

The Non-Neutrality of Agrarian Structure: U-Shaped Farm Size–Productivity Relationships in Kenya

Kenya is unique among African countries for its commitment to market activation. Agriculture in Kenya's highlands has been highly commercialized since the colonial period. Agrarian structure today is variegated, with units ranging from a single acre to hundreds of acres in size. Blarel et al. analyze microeconomic data on 109 small and medium farms in the Njoro region of Kenya. Two patterns they observe are of particular interest here.

First, productivity varies strikingly with farm size, as illustrated by the fitted regression curves in figure 1. Output represents the per acre value of maize-beans, wheat, and livestock products at sample average prices. A statistically significant U-shape characterizes both output and family income (the latter is output less the value of all inputs except family labor). Profits (family income less the imputed value of family labor) increase monotonically with farm size. The intensity of family labor application on small farms is clear, driving profits down sharply on smaller farms. Profits even fall below zero for the smallest farms, suggesting that the market wage, at which the value of family labor is imputed, overstates the real opportunity cost of family labor to farm households.

A second size-related pattern of interest is the allocation of land to various activities, illustrated in figure 2. Two features are immediately apparent. Farms of all sizes allocate about the same amount of land to production of the staples maize and beans. And wheat, a purely commercial crop in Njoro, abruptly becomes the dominant activity on larger farms. The remaining sections of this paper explore the rationale and implications of this structural non-neutrality, with particular emphasis on the role of access to capital.

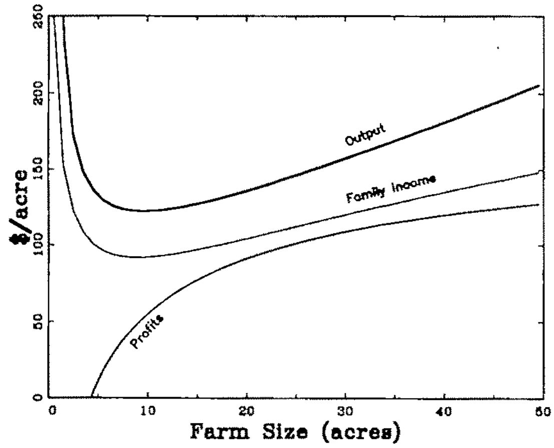

Figure 1. Output and net returns per acre

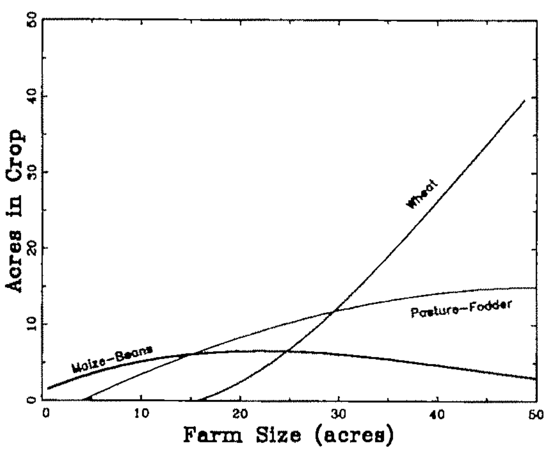

Figure 2. Area by crop activity

Ex Ante Capital Access and Farm Productivity

Rationed access to *ex ante* capital, interacting with an imperfect labor market, is one possible explanation for the striking farm size-farm productivity relationships displayed in figure 1.[3] The CGE model developed in Carter and Kalfayan can be used to explore this explanation. Agent behavior in their model is constrained by a capital constraint:

(1) $p_f F + wL_d + R_0 \leq w\Phi(L_s) + \beta(T)$,

where $\beta(T)$ is the amount of quantity rationed working capital available to an individual with land endowment T; F is fertilizer and other nonlabor purchased inputs; L_d is total quantity of hired labor in time units; R_0 is family subsistence needs less savings; $\Phi(L_s)$ is the number of days employed as a function of days supplied to the labor market, L_s, ($\Phi' > 0$ and $\Phi'' \leq 0$); and p_f and w are the market fertilizer price and wage per unit of labor time, respectively. Let μ denote the Lagrange multiplier or shadow price corresponding to constraint (1).

In addition, hired labor must be supervised so that the total units of effective labor (Tl) from L_h units of own and L_d of hired labor are

(2) $$Tl = L_h + \gamma(l_h)L_d,$$

where, assuming an informal family labor supervision technology, the effectiveness of supervision depends on the density of family labor per acre, l_h, and $\gamma < 1$ for all l_h and γ', $\gamma'' \geq 0$.

Maximization of household income subject to constraints (1) and (2) admits a variety of solution regimes depending on prices and the agent's land endowment. For a capital-constrained semiproletarian agent who supplies labor to the market ($\mu > 0$, $L_s > 0$ and $l_d = 0$), quantities of labor and fertilizer will be chosen to fulfill the following conditions:

(3a) $$q_l = (1 + \mu)w\Phi', \text{ and}$$

(3b) $$q_f = (1 + \mu)p_f.$$

For a capital-constrained labor-hiring farm ($\mu > 0$, $L_s = 0$ and $l_d > 0$), labor and fertilizer are chosen to fulfill

(4a) $$q_l = (1 + \mu)w/\gamma(l_h), \text{ and}$$

(4b) $$q_f = (1 + \mu)p_f.$$

Interpretation of (3) and (4) is straightforward. Inputs are used until marginal factor productivities are equated to real economic costs, defined as the direct opportunity cost marked up by the shadow price of working capital ($\mu > 0$). For the labor supplying agent (3a), the direct cost of labor is the market wage times the marginal employment probability. For the labor-hiring agent (4a), the direct cost of labor appears as an efficiency wage, the market wage paid per unit of effective labor input.

As indicated by first-order conditions (3) and (4), marginal factor products measure the severity of labor market imperfections and the shadow price of *ex ante* capital. All farmers in the Kenya sample devote some land to the pro-

[3] In the Kenya data, farms less than 3 acres in size borrow *ex ante* an average of 2 shillings per acre; large farms borrow 250 shillings per acre.

duction of a maize-bean intercrop. Fitting a standard Cobb-Douglas production function to the data on this fairly homogenous technology yields the following econometric results:

$$(5)\quad \ln Q = \underset{(5.36)}{3.64} + \underset{(8.05)}{0.45} \ln F + \underset{(2.74)}{0.23} \ln L + \underset{(2.72)}{0.26} \ln T \quad (R^2 = 0.78),$$

where all variables (except land) are converted to money units using sample average prices. With this monetary definition of inputs and outputs, marginal products represent the net increase in gross income realized from the application of an additional shilling's worth of any particular input. Exclusive of capital costs, profit-maximizing resource allocation at sample average prices would apply inputs to the point where each input's marginal product equals one.

For each observation i, the marginal product for factor X can be calculated as follows using the estimated parameters given in (5):

$$(6)\quad MPX_i = \partial Q_i/\partial X_i = (\partial \ln Q_i/\partial \ln X_i)Q_i/X_i = \beta_x Q_i/X_i,$$

where β_x is the estimated Cobb-Douglas regression coefficient for input X. In order to test for systematic size-sensitivity of markets, calculated marginal products were regressed on farm size:

$$(7)\quad MPL = \underset{(6.14)}{0.28} + \underset{(8.06)}{0.05T} - \underset{(-4.96)}{0.0001T^2} \quad (R^2 = 0.48)$$

$$(8)\quad MPF = \underset{(14.97)}{4.31} - \underset{(-2.78)}{0.10T} + \underset{(2.41)}{0.001T^2} \quad (R^2 = 0.07).$$

The estimated regression functions (7) and (8) are displayed in figure 3. The dashed horizontal line indicates the level to which marginal factor productivities would be driven assuming profit maximization and an interest rate of 20%.

On the (debatable) assumptions that purchased inputs are not quantity rationed and that their prices do not systematically vary with farm size, figure 3 shows that the shadow price of *ex ante* capital is very high on the smallest farms (300% for a 5-acre farm) and declines with farm size to about 100% for a 40-acre farm. The pattern for labor allocation is quite the opposite, as figure 3 shows. The smallest farms apply labor until its marginal product is only a fraction of the market wage, while the efficiency wage for larger farms (that is, the wage per-unit of effective labor effort) appears to be above the market wage.

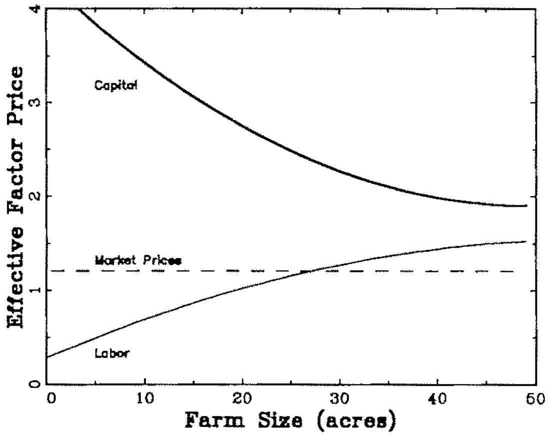

Figure 3. Effective factor prices

Unlike the conventional monotonic, inverse farm size–farm productivity relation, the U-shaped relation discussed above points to constraints which inhibit the productivity of smallholders. The analysis in this section suggests that, despite their access to cheap labor, the potential hyperproductivity of small farms is eventually overwhelmed by countervailing capital constraints.

Let $\pi(w, p_f, T)$ be the optimum value function defined by maximization of household income subject to constraints (1) and (2). For any given set of parameters, $\pi(w, p_f, T)$ can be used to explore the interacting impact of these various market failures on a given farm unit's incentives to change its scope of cultivation. For a farm of size T, the reservation price for land may be defined as

$$(9)\quad \rho(T) = \sum_{t=1}^{\infty} \Delta(T)/(1 + \mu(T + \epsilon))^t,$$

where $\rho(T)$ is the reservation price, $\Delta(T) = [\pi(w, p_f, T + \epsilon) - \pi(w, p_f, T)]/\epsilon$ is the per acre increment in income which could be optimally gained if ϵ additional hectares of land were owned by a farm of initial size T, and $\mu(T + \epsilon)$ is the discount rate calculated as the shadow price of capital specific to the size of the expanded farm unit.[4] Following the analysis of the impact of *ex*

[4] As written, (8) presumes that current prices will persist into the future. Also note that households, who by virtue of their small landholding supply much of their labor to the market, may have a high reservation price for land because landownership effectively permits them to earn a return on their labor by selling it to themselves.

post capital constraints on farm resource allocation and productivity, equation (9) will be estimated using the Kenya data.

Ex Post Capital Access and Agricultural Commercialization

Ex ante capital constraints shape production strategies by limiting small farmers' access to working capital. Production strategies may also be affected by capital constraints *ex post*, through their effect on household food security. In particular, constrained access to *ex post* capital as consumption insurance may contribute to Njoro farmers' decisions to produce maize-beans before allocating land to wheat, driving the patterns in figure 2.

A simple safety-first model (based on Wiebe) illustrates this point. Consider a household which may allocate land to the production of maize and wheat. Net returns to wheat production are on average twice as high in Njoro than are net returns to the production of maize. Nevertheless, specialization in wheat implies reliance on maize markets for consumption; despite state efforts to guarantee commodity prices, this remains an uncertain proposition.

If returns to wheat are both higher on average and more variable in real terms than are returns to maize, maximization of expected returns may periodically fail to secure consumption needs, here defined as a minimum maize requirement C for each of the household's N-resident adult equivalent members. In this case, the household faces a nontrivial problem in choosing, before yields and prices are known, the proportion q of its land to allocate to wheat.

Given q, average family income per farm acre can be expressed as a linear combination of family income to wheat (FI_w) and to maize (FI_m):

$$FI_q = qFI_w + (1 - q)FI_m.$$

The critical level d of family income per farm acre required to meet consumption needs is moderated by the household's access to *ex post* capital R:

$$d = (NC - R/p_m)/T,$$

and may be greater than, less than, or equal to zero accordingly. Because R is denominated in real terms, d is itself a random variable whenever $R \neq 0$.

Objective risk—the probability of a food deficit in any one year—depends on the distributions of net income $FI_q - d$ for all $q \in [0, 1]$. Given N, R, and T, objective risk depends in turn on the probability density functions of prices and yields of maize and wheat. Let these be described by cumulative distribution functions F_q of net income such that

$$F_q[0] = Pr[FI_q - d < 0].$$

Formally, the household's problem is then to

$$\max_q E[FI_q], \text{ subject to } F_q[0] \leq \alpha; \quad \text{otherwise, } \max_q F_q^{-1}[\alpha];$$

where α represents the highest level of objective risk acceptable to the household. The household chooses q to maximize expected income, but in so doing, it selects only from those crop combinations which offer acceptably low objective risk. When no choices of q satisfy the "chance constraint" the household must relax its decision making criteria and minimize its losses.

This model derives q^*, the optimal commercialization level, as a function of N, R, and T. Given N and T, three cases can be distinguished on the basis of access to capital *ex post*.

Case 1: $F_q[0] \leq \alpha$ for all q. If *ex post* capital access is sufficiently liberal (and hence d sufficiently low) that all choices of q satisfy the chance constraint, the household's problem reduces to the maximization of expected returns. This leads to a simple corner solution; since $E[FI_m] < E[FI_w]$, the household chooses $q^* = 1$.

Case 2: $F_q[0] \leq \alpha$ for $q \in [0, q' < 1]$, where $F_{q'}[0] = \alpha$. When capital access is less favorable, however, d is higher. In this case not all levels of q offer acceptably low risk; the chance constraint may be satisfied only for *some* q. Then the chance constraint is binding, and the household sacrifices some degree of expected income by choosing $q^* = q'$ in order to reduce objective risk to an acceptable level.

Case 3: $F_q[0] > \alpha$ for all q. When *ex post* access is tightly constrained, the income required of agriculture to meet basic needs becomes very high. If no choices of q satisfy the chance constraint the household must relax its decision-making criteria; choice of $q^* = 0$ minimizes losses in bad years.

Even if labor and *ex ante* capital markets are fluid, the same agricultural opportunities are technically available to all, and objective risk thresholds are identical, optimal strategies may vary across households according to their access to capital *ex post*. Specifically, case 1 households are sufficiently insulated from the risk of

a food deficit that they can afford to commercialize completely. Case 2 households are less well cushioned and produce food first before allocating land to wheat, while case 3 households are sufficiently vulnerable that they are forced to specialize in production of maize.

In general, household size N and farm size T are not constant but vary from farm to farm. If access to capital *ex post* mirrors the size-related pattern found in an earlier section with regard to access *ex ante* in Njoro, cases 1 and 2 would then characterize the sample's larger farms, while case 3 would better describe its smaller farms. These observations are consistent with the land allocation patterns illustrated in figure 2: larger farms commercialize to a greater degree than do smaller farms, and all farms appear to seek food security first before allocating land to wheat.

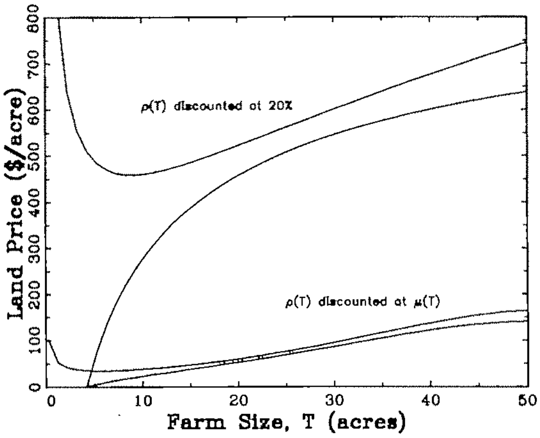

Figure 4. Imputed land price, $\rho(T)$

Willingness to Pay for Land and the Economics of Structural Evolution

The preceding two sections have shown how size-related patterns of access to capital generate size-related patterns of resource allocation and productivity in Kenya's smallholder sector. Agricultural performance is strongly influenced by agrarian structure, in keeping with the theoretical propositions of Eswaran and Kotwal. In addition, evidence of the non-neutrality of size suggests that agrarian structure is itself under pressure to evolve over time. The family income and profits measures discussed earlier in the paper offer simple reduced-form estimates for average returns to land reflecting smallholders' structure-sensitive choices. As such, these estimates can serve as crude approximations of a measure of the marginal returns to land needed to estimate the land reservation price $\rho(T)$ defined in equation (8).

Alternative estimates of the land reservation price are presented in figure 4. The first set of estimates assumes a constant rate of interest available to all farms, and simply scale up the net returns illustrated in figure 1. The second set uses as the discount rate the size-sensitive shadow price of capital which was estimated in equation (7). Capital market constraints are here seen to drive imputed reservation prices down for all farms, and for the smaller farms in particular.

Clearly, structure-sensitive capital market and resource allocation patterns interact in Njoro to generate incentives for land transactions which vary dramatically across the existing distribution of farm sizes. Specifically, as land markets become active, this suggests that large farms will enjoy a systematic capacity to outbid smaller farms for available land. Questions regarding the long-term path of agrarian structural evolution in a market context are thus a natural and important extension of conventional concerns about productivity in the short run. Access to capital, both *ex ante* and *ex post,* plays a critical role in shaping that path over time.

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The Relationship between Credit and Productivity in Chinese Agriculture: A Microeconomic Model of Disequilibrium

Gershon Feder, Lawrence J. Lau, Justin Y. Lin, and Xiaopeng Luo

Credit is an important element in agricultural production systems. It allows producers to satisfy the cash needs induced by the production cycle which characterizes agriculture: preparation, planting, cultivation, and harvesting of the crops are typically done over a period of several months in which very little cash revenue is earned, while expenditures on materials, purchased inputs, and consumption must be made in cash. Cash income is received a short time after the harvest. In the absence of credit markets, farmers would have to maintain cash reserves so as to facilitate production and consumption in the next cycle. The availability of credit allows both greater consumption and greater purchased input use and thus increases welfare of the farmers.

If a producer faces an infinite supply of liquidity at a given price, the production decisions will be independent from consumption decisions, as has been shown in the household models of Singh, Squire, and Strauss. However, asymmetric information, and adverse selection typically prevail in credit markets, giving rise to credit rationing as an optimal behavior (Stiglitz and Weiss). Furthermore, government intervention in the form of interest rate ceilings or subsidized interest rates is common in many countries' agricultural sectors, necessitating rationing. When credit is rationed, some borrowers cannot obtain the amount of credit they desire at the prevailing interest rate, nor can they secure more credit by offering to pay a higher interest rate. In such circumstances, liquidity can become a binding constraint on many farmers' operations.

When liquidity is a binding constraint, the amounts and combinations of inputs used by a farmer deviate from their notional optimal levels (the levels that would have been utilized if liquidity were not a binding constraint). The marginal contribution of credit is therefore to bring input levels closer to the optimal levels, thereby increasing output and, because the quantity of land is fixed, yield. This potential gain in productivity is one motivation underlying many government programs seeking to provide more credit to the farm sector. An important issue in the context of agricultural credit policy is the magnitude of the expected productivity gain. If the marginal productivity effect of credit is small, then the resources may be more beneficially deployed elsewhere. Assessment of the expected productivity gain is not trivial because the effect of credit is likely to differ between liquidity-constrained and unconstrained farm households.

Some studies attempt to identify the effect of credit by estimating separate production functions or supply functions for borrowers and nonborrowers and then proceeding to compare the estimates (see review in David and Meyer, pp. 206–15). One major weakness of this approach is the implicit assumption that all borrowers and all nonborrowers are, respectively, homogenous with respect to their credit demand/supply situations. This assumption is often not valid, as many nonborrowers do not borrow because they actually have sufficient liquidity from their own resources and not because they cannot obtain credit, while some cannot borrow because they are not creditworthy. Similarly, the marginal effect of credit may actually be zero for borrowers for whom liquidity is not a binding constraint.

The same criticism applies to other studies in which all sampled observations are pooled to es-

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timate production functions (or output supply functions) with credit as a production input or as a supply determinant. As will be argued in a subsequent section, the supply function is different (both in parameters and in variables) depending on whether liquidity is a binding constraint. Estimates which do not take account of these restrictions on the specification are therefore flawed.

The present study reports an econometric analysis of the effect of credit on output supply which avoids some of the aforementioned pitfalls. The central feature is the recognition that credit transactions are not necessarily in equilibrium at the household level. That is, the amount of credit desired and the amount offered are not necessarily equal, so that credit supply rationing (with unsatisfied demand) and nonborrowing (while supply is potentially available) are both possible. The analysis utilizes cross-sectional household-level data from a study area in northeast China, obtained in a recent farm survey designed by the authors. The plan for the paper is as follows: the next section provides background on the farm sector and the rural credit market in China and describes the specific study area and data utilized in the analysis. The formal model underlying the empirical analysis then is discussed. It is followed by a discussion of the econometric procedure and the empirical results. The last section discusses the implications of the results.

China's Farm Sector and Rural Credit Market

China introduced a smallholder agricultural production system in a series of reforms between the years 1979–84. The "household responsibility system" made individual households, rather than the communes to which they belonged, the decision makers and managers of their own farms. Individual families were allocated land by the communes on leases that run typically for fifteen years. The improved incentives brought about a significant increase in agricultural output and in rural income (Lin). While prior to the reforms there was only limited interaction between households and financial institutions, the emergence of smallholder agriculture implies that many households now need liquidity for seasonal production and consumption or longer-term credit to finance investment, construction, and ceremonial social events.

Most of agricultural households' transactions with the formal financial sector are done with the rural credit cooperatives (RCCs).[1] The interest rates for agricultural loans (as well as other loans) made by formal credit institutions are fixed by the government, with some variations according to loan categories. In 1987, the rates of interest for agricultural loans ranged between 7% and 14%. The degree of interest subsidy is believed to have been small.

There is evidence that, following the introduction of reforms, the volume of liquidity obtained from informal sources is substantial in China. Jiang asserts that noninstitutional sources contribute roughly half of the credit volume in rural areas. Feder et al. (1989) report non-institutional credit shares of between one-third and two-thirds in several study areas. The most common sources of informal credit in China are relatives and friends. Most of such loans carry no interest charges. Possible reasons for the absence of a substantial profit-motivated informal credit market in China are discussed in Feder et al. (1990b). They include unclear legal status, residual ideological resistance, and absence of collateral assets.[2]

The present study relies on data collected in December 1987 in Gongzhuling. Gongzhuling is located in Jilin province, within the corn belt of northeastern China where agroclimatic conditions dictate essentially one corn season a year. The original sample consists of 200 households selected at random from eight randomly selected townships. The information gathered covers inputs, outputs, financial assets, credit transactions, and household characteristics. Thirteen households are deleted after determining that their main activity was not agriculture or that their situation was unusual (e.g., a widow maintaining a home garden plot).

The data show that nearly three-quarters of the sample borrowed from formal sources (essentially the RCCs) during the study season. The frequency of informal credit transactions is much lower than that of formal transactions (about one fifth of the sample), and three-quarters of these loans were provided free of interest. Given the significant differential between the rates of interest on the two types of loans, this may be taken as evidence that informal credit is not a good substitute for formal credit due to limited fungibility (otherwise every borrower would ex-

[1] Greater detail on the credit market in rural China and in the study area is provided in Feder et al. 1989, 1990b.

[2] Land is on a fifteen-year lease and until recently use rights could not be transferred.

haust his or her informal credit first before going to the RCC). The share of formal credit in the total volume of new credit is 66.5%.

Table 1 presents the distribution of loans by purpose and by type of lender. It is readily apparent that the predominant stated purpose of formal loans (all of which are short-term) is for the financing of current production. Most of the informal credit is reported to have been obtained for purposes other than production, with construction and social expenditures appearing dominant. Informal loans contracted for these purposes, however, cannot be diverted easily to finance day-to-day consumption or production because the lenders, mostly relatives and friends, can easily monitor compliance. The bulk of the fungible credit, defined as credit which is not granted for easily monitored purposes, in the study area thus comes from the formal sector (87%).

Given the dominance of formal credit, a key issue for the present study is the extent to which its supply is a constraint on households' desired activities. The survey data collected permit an answer to this question. Borrowing households were asked if at the going rates of interest they would have liked more institutional credit than the amount they were actually granted. Households which did not borrow were asked the reason for not borrowing. The most common reason for not borrowing was availability of sufficient own resources. The borrowers who indicated a desire for more credit and the nonborrowers who responded that they could not obtain credit are classified as credit-constrained. As reported in table 2, about 37% of the farm households in Gongzhuling were constrained by credit according to this classification. The liquidity position of credit-constrained households as compared to nonconstrained households is compatible with intuitive expectations: They have significantly lower deposits in financial institutions, and overall, their liquid resources per unit of land are 12% below those of unconstrained households.

A Model of Farm Household Consumption, Production, and Investment

Suppose the household considers the allocation of resources at its disposal at the beginning of the production period between the following uses: (*a*) current consumption, (*b*) investment, (*c*) the purchase of variable inputs for current production (including labor and fertilizers). Variable inputs, in combination with land and existing capital, will produce this period's output. Investment will not mature by the time this period's output is produced, but its contribution to the household's welfare may be accounted for through a valuation function which summarizes the contribution of capital to the future consumption stream. The household's initial endowments of liquid resources, family labor, capital, and land (the latter two assumed not convertible to liquidity during the period) can be augmented by borrowing at the beginning of the period. Whether the household can borrow the entire desired amount or is constrained by a binding upper limit on the availability of credit is of considerable consequence because it determines whether production decisions are separable from the consumption decisions. The household is assumed to maximize a utility function defined over consumption per family member in the current and next period, plus the utility of future streams of consumption summarized by the valuation function of next period's capital, per family member. The optimization can be carried out under two scenarios: (*a*) The supply of credit is greater than or equal to the demand (i.e., credit constraint not binding), and (*b*) the supply of credit is less than the notional demand for credit (credit constraint binding).

The essence of the results of such a model[3] is that under case (*a*) above, the supply of output is not affected by the level of liquidity (includ-

[3] A rigorous derivation of model implications is available to interested readers from the authors.

Table 1. Distribution of Loan Purposes by Type of Lender (Percent)

Source of Loans	Sample Size (Number of Loans)	Purpose					
		Production	Farm Equipment	Construction	Consumption	Social (Wedding, Funeral, etc.)	Other
Formal	209	92.3	4.3	1.9	0	1.0	0.5
Informal	44	9.1	4.6	20.5	15.9	27.3	22.7

Table 2. Extent of Formal Credit Constraint

Category	Sample Size (Number of Households)	% Constrained
Borrowers	145	41.3
Nonborrowers	42	28.3
All	187	37.4

ing credit), the size of the household's own family labor force or the total size of the household. The parameters of the output supply function in this case are determined by the production function alone. Under case (*b*), however, output supply is positively affected by increases in liquidity (e.g., increased credit supply) and in the household's labor endowment, while the effect of total household size is indeterminate. Increases in the initial endowments of land and capital would have a positive effect on output supply in both cases (*a*) and (*b*), while they would have an indeterminate impact on input demands, depending on substitutability. The parameters of the output supply function under case (*b*) are determined by both the production function and the utility function.

Econometric Specification and Empirical Results

The econometric model most suitable for estimating the output supply function with the data available to us is the switching regression model with an endogenous criterion function described in Maddala (pp. 223–228). The model postulates for any observation i

$$Y_{1i} = \beta_1 X_{1i} + U_{1i} \quad \text{iff } \gamma Z_i + U_i \leq 0 \tag{1}$$

$$Y_{2i} = \beta_2 X_{2i} + U_{2i} \quad \text{iff } \gamma Z_i + U_i > 0 \tag{2}$$

where X_{1i}, X_{2i}, and Z_i are vectors of exogenous or predetermined variables; β_1, β_2, and γ are the corresponding vectors of parameters; and U_{1i}, U_{2i}, and U_i are random disturbances. Y_{1i} and Y_{2i} are two possible values of the dependent variable, only one of which is actually observed for any given household, depending on the value of the (unknown) criterion function $\gamma Z_i + U_i$. The random disturbances are assumed to have a trivariate normal distribution, identically and independently distributed across households. Applied to the particular issue at hand, equations (1) and (2) may be viewed as the output supply equations under a nonbinding and binding liquidity constraint, respectively. The criterion for whether liquidity is binding or not is whether the demand for credit exceeds credit supply, and the criterion function $\gamma Z + U$, in our case, is the excess credit demand function (i.e., demand minus supply). Excess credit demand is not directly observable. However, from the survey responses, we know whether a given household is constrained or unconstrained by liquidity. Using data on the dichotomous responses, the vector of parameters γ can be estimated up to a proportionality constant by a probit procedure. The estimated parameters are then used to generate Mills ratios, which are incorporated in the second-stage estimates where equations (1) and (2), with their Mills ratio corrections, are estimated by a linear regression. Under model assumptions, the estimated coefficients are consistent and asymptotically normal, and with appropriate corrections to their estimated variance-covariance matrix (because of the heteroscedasticity of the stochastic disturbance terms in the second-stage estimates) can be subjected to statistical tests based on normality.

The empirical specification of the variables which constitute the vector Z involves both determinants of credit demand and credit supply. Thus, in the case of variables which affect both demand and supply in the same direction, one cannot predict a priori the expected sign. These variables are (with the expected effect on the probability of being credit constrained indicated in parentheses for those with an unambiguous effect): (*a*) land; (*b*) capital; (*c*) number of adults (−); (*d*) number of dependents;[4] (*e*) education; (*f*) farm experience; (*g*) savings in financial institutions (−); (*h*) total initial liquid assets (−); (*i*) outstanding debt to financial institutions (+); (*j*) total outstanding debt (+); (*k*) last season's income (−); (*l*) previous loan default dummy (+). In addition, eight dummy variables for townships were introduced. The results of the probit estimates are presented in table 3.[5] Two estimated coefficients are statistically signifi-

[4] The number of dependents plus number of adults constitute household size. While the number of adults has an unambiguous effect, household size (and consequently the number of dependents) does not.

[5] The households with special large-scale ceremonial expenditures were not included in the econometric analysis, as their liquidity requirements and borrowing patterns could be quite different. This reduces the sample size for the econometric analysis to 156. However, including these households, with appropriate dummy variables and interaction terms, does not alter the nature of the results qualitatively.

Table 3. Estimated Coefficients of Probit Model (Probability of Being Credit-Constrained)

Variable[a]	Estimated Coefficient (t-value)
Land	−.212
	(.505)
Capital	−.029
	(.265)
Number of adults	.282
	(1.950)
Number of dependents	.093
	(.509)
Education	−.101
	(1.502)
Farm experience	−0.25
	(1.666)
Savings in financial institutions	−.121
	(2.223)
Total initial liquid assets	.376
	(1.552)
Outstanding debt to financial institutions	−.053
	(.977)
Total outstanding debt	.057
	(1.182)
Last season's income	−.974
	(2.973)
Previous loan default	.587
	(1.260)
Percent correctly predicted	.820
No. of observations	156

[a] The equation also included eight township dummy variables. These are not reported.

cantly different from zero at the 5% level of significance and have the theoretically predicted sign: savings in financial institutions and last seasons's income. Eighty-two percent of the observations are properly classified as being credit constrained or unconstrained, implying a fairly good fit.

The reduced-form output supply equation for liquidity-constrained households, estimated with the double-log specification, involves the following variables (with the direction of the expected effect noted in parentheses): (*a*) total liquidity[6] (+); (*b*) number of adults (+); (*c*) number of dependents (?); (*d*) land (+); (*e*) capital (+); (*f*) education (+); (*g*) farm experience (+). The specification for the households not constrained by liquidity is similar except for the first three variables, which do not theoretically belong in the reduced form for output supply.[7] The estimated coefficients are reported in table 4.

In the output supply equation for constrained households, (column 1) the estimated coefficient of the total liquidity variable is positive and statistically significantly different from zero at the 5% level of significance, but the number of adults and the number of dependents do not have statistically significant estimated coefficients. The hypothesis that all three variables do not affect the supply of output for constrained households has a F-statistic of 2.96 and is rejected at the 5% level of significance, confirming the theoretical predictions of the model. The quantity of land is an important and statistically significant determinant of output supply for constrained and unconstrained households (the estimated coefficients of the output supply function for the latter group are reported in column 2). It is also worth noting that capital, education, and farm experience have statistically significant positive effects on output for the credit-unconstrained households but have statistically insignificant effects for the credit-constrained households. This finding suggests that capital, education, and experience are less likely to contribute to output if the farmer's choices are constrained by liquidity.

While under the assumptions of our model it is not appropriate to estimate the output supply equation for the unconstrained households with the inclusion of liquidity and household composition variables (liquidity is theoretically endogenous for such households, and the estimated coefficients would be subject to simultaneity bias), we experimented with the estimation of such a hypothetical counterfactual case on the assumption that the classification was wrong and therefore these households were liquidity-constrained. The results (column 3 in table 4) indicate that none of the estimated coefficients of the first three variables are statistically significantly different from zero (the hypothesis that all three are not significant has a F-statistic of 0.55 and cannot be rejected at any level of significance), implying that the counterfactual case is not borne out empirically. Another experiment was the estimation of the model using the whole sample without separation, that is, as

[6] This consists of cash value of product inventory, deposits in financial institutions, and fungible formal loans. Informal credit was assumed nonfungible as observed in the second section. Total liquidity differs from the total initial liquid assets in the probit equation, which do not include current fungible credit.

[7] The equations should have included output and input prices. However, because the data are derived from a cross-section within a confined geographical area, there is no price variation, and price variables are omitted.

Table 4. Estimated Coefficients of Second-Stage Switching Regression Model for Output Supply (Reduced-Form)

Variable[a] Regression	(1) Credit Constrained (N = 48)	(2) Credit Unconstrained (N = 108)	(3) Credit Unconstrained Counterfactual (N = 108)
Total liquidity	.183		.042
	(2.951)[b]		(1.261)
Number of adults	.015		.001
	(.641)		(.004)
Number of dependents	−.020		−.005
	(.538)		(.247)
Land	.863	.875	.846
	(8.166)	(18.120)	(15.202)
Capital	.027	.051	.052
	(1.193)	(3.287)	(3.306)
Education	−.004	.018	.018
	(.261)	(2.216)	(2.206)
Farm experience	−.028	.063	.062
	(.533)	(2.324)	(2.250)
R^2	.863	.867	.869

[a] Regressions included also eight dummy variables for townships and the Mills ratios computed from the first-stage probit. These are not reported.
[b] Numbers in parentheses denote t-values.

if all households were liquidity-constrained. The results show that the estimated coefficient of total liquidity in the output supply equation would have been about two-thirds of that in column 1. Predictions based on the wrong estimated coefficients would thus lead to significantly inaccurate assessments of the effect of credit on output supply.

Implications

Based on the estimated coefficients, if every credit-constrained household in the sample is given an additional credit of 17.82 yuan (equal to 1% of the average level of liquidity of the credit-constrained households), the total output of these households may be projected to increase by 201.08 yuan, or approximately 0.04% of the total output. Thus, on average, one additional yuan of liquidity (credit) would yield $201.08/(17.82 \times 48) = 0.235$ yuan of additional gross value of output. These results suggest that for the area of China covered in the present study, a significant proportion of the short-term credit provided by the rural credit cooperatives as "production credit" may actually be utilized for consumption and investment. Indeed, medium- and long-term formal credit is practically nil among the agricultural households in our study areas, and a similar picture is given by aggregate statistics. Rolled-over short-term credit is sometimes utilized to finance small-scale investments. A recent study by Feder et al. (1990a) finds that the diversion of short-term credit for farm investment is about 40% for an average household in the study area. This, in turn, implies that almost a third of the formal credit is utilized for consumption (whether of current goods or durables).

The results of the study highlight two important factors which should be considered when evaluating the likely impact of agricultural credit expansion: (*a*) Not all farmers, and sometimes only a minority, are constrained in their farming operations by inadequate credit; (*b*) expanded supplies of formal credit will be diverted in part to consumption, thus the likely output effect will be smaller than that which is expected when all funds are assumed to be used productively. These ideas have been propounded by the Ohio State school critics of credit supply-led development schemes. The present paper thus provides empirical verification of these views.

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Analyzing the Farm-Level Impact of Agricultural Credit: Discussion

Richard L. Meyer

In the 1960s and 1970s, many studies were conducted to evaluate and measure the demand for agricultural credit in developing countries and the impact of many subsidized credit programs then in effect, especially those designed to increase small farmer access to loans. The 1973 AID spring review of small farmer credit, a comprehensive review of programs in several developing countries, represented the first major occasion when serious doubts were raised about the real impact of such programs.[1] Our critical review of research conducted up to the late 1970s led us to question the basic methodology of many impact studies and, therefore, their empirical results (David and Meyer). One fundamental problem was that much of the research failed to account for the wide range of production, consumption, and investment activities undertaken by a rural household. Given the fungibility of farm-household cash flow management, it is difficult to identify the true impact of loans supposedly given for farm production. Production loans from financial institutions may not contribute much additionality to farm input use and output if, because of fungibility, they simply substitute for own savings or other sources of loans.

A second shortcoming concerned the well-known attribution problem. Many studies tried to measure credit impact by observing differences between borrowers and nonborrowers or before and after borrowing. But loans were often granted as part of multipurpose agricultural programs which provided subsidized inputs and intensive extension services in addition to credit. Often the authors simply attributed to credit any positive differences found between borrower and nonborrower groups, thereby ignoring the possible impact of these inputs and extension.

A third problem arose because of the concessionary loan interest rates employed in most programs. Low interest led to excess demand for loans and the nonprice rationing that occurred often resulted in large loans to farmers with greater factor endowments, access to better inputs and technical information, and better management. Therefore, borrowing could be the result rather than the cause of differences observed between borrowers and nonborrowers.

The interesting studies presented in this session employ new theoretical and quantitative approaches to explore more contemporary credit impact issues in three widely different developing countries. In the first paper, Anderson analyzes the possible link between changes in farm labor contracts and the large increases during the past decade in real interest rates on rural loans for sugarcane farmers in northeast Brazil. This research is particularly interesting because no developing country matches Brazil in the magnitude of credit subsidies used to stimulate agricultural growth during the past couple of decades. Anderson notes that during the cheap credit period of the 1970s, permanent employment grew faster than temporary (volante) employment because permanent contracts became an increasingly attractive way to guarantee the availability of harvest season labor. During the 1980s, however, the permanent labor share reportedly declined. On her sample farms, the decline was from 65% in 1978–79 to 57% in 1988–89. Her review of empirical data leads her to discount the role of rising wage rates and cane prices, extended social security benefits, mechanization, and herbicide use in explaining increased reliance on temporary harvest labor. Rather, she believes it is the result of the sharp increase in interest rates, from a negative 60% or 70% real rate in the early 1980s to a positive 7% to 9% by 1987, that raised the cost of slack season labor. Her arguments are plausible and well presented, but she lacks robust time-series data to rigorously test them and her cross-sectional model does not contribute strong evidence. No infor-

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[1] This review was the last of the large-scale reviews conducted by AID of specific development issues. The results of this ambitious undertaking are summarized in Donald.

mation is provided to show if the borrowing patterns of sugarcane farmers actually changed over time in response to the interest rate changes. We should expect that a long regime of subsidized rural lending, such as existed in Brazil, would have distorted resource allocation. Shifting to positive interest rates should encourage adjustments which, among other impacts, could alter labor relations. If the huge credit subsidies led to a build-up of mechanization on farms and in sugarcane mills, their abrupt removal could prompt a reduction in aggregate employment in the entire sugar sector. Under such circumstances, interest rate reform would likely have broad consequences.

In the second paper, Carter and Wiebe model how differential farm access to production and consumption credit can influence productivity and agricultural structure in the Kenyan highlands. Without describing the characteristics of the sample, they analyze patterns of output, net returns, family income, and profits per acre for 109 farms. They find the typical result that small farms produce relatively fewer commercial crops and earn lower income and profits than larger farms. They model a household that must finance subsistence, purchased labor, and fertilizer out of wage earnings and borrowed funds. They assume, without providing evidence, that credit is a function of land endowment, so it is not surprising that small farmers face binding working capital constraints because of limited family labor and borrowing capacity. This helps explain the pattern of land allocation and related farm profits and suggests that large farms will be able to outbid small farms when land markets become active.[2]

In a sense this paper takes us back more than twenty years because it is precisely the concern about differential access to credit that prompted the subsidized small farmer credit programs of the 1960s and 1970s. But evidence subsequently showed that targeted lending is not effective in resolving equity problems (Adams and Meyer). What we can hope for is that financial institutions will become increasingly sophisticated over time so that, if Kenyan lenders currently ration loans exclusively on land size, they will increasingly look at broader debt repayment capacity criteria in their future lending. It would have been interesting to have learned the authors' views about credit supply problems and their possible reform, in addition to the traditional warning about productivity and structure problems.

In the final paper, Feder et al. explore how credit constraints may affect farm efficiency following the adoption of the household responsibility system in northeast China. The strength of this research is in the careful analysis of survey data described in this and their other referenced papers. These papers really need to be read as a collection to appreciate fully their analysis. This particular paper reports on the data analyzed from a sample of 187 households in the corn belt of northeastern China. The other papers analyze data collected in other regions.

The authors are concerned that Chinese farmers face binding liquidity constraints leading to suboptimal use of production inputs. Unlike other countries with well-developed informal lenders, they argue that noninstitutional credit in this region is mostly provided interest free by relatives and friends for purposes other than production in circumstances that can be effectively monitored. Thus, the bulk of fungible credit comes from institutional sources.

Farmers who borrowed institutional credit but indicated a desire to borrow more at current rates of interest and nonborrowers who responded that they could not obtain such credit were classified as credit-constrained. This group, representing 37% of the farmers, also reported significantly lower deposits in financial institutions and had 12% less liquid resources per unit of land. In an earlier paper (1989), Feder et al. show that credit-constrained farmers had lower levels of input use and lower output than nonconstrained farmers in the sample. Their econometric results suggest that a doubling of formal loans would lead to an output gain of 3.8%. An additional dollar of liquidity in short-term funds would yield about 23¢ of additional value, but the long-term effect would depend on the return generated from funds diverted to investment.

Intriguing credit issues remain in this research. What explains the reported unsatisfied demand for credit? Relatively few farmers report input supply constraints. No strong evidence is presented of rapid mechanization or enterprise changes. Land cannot be easily transferred, so presumably farm size is fairly constant. In addition to the new production possibilities, the Chinese reforms seem to have unleashed a strong demand for housing investment, consumption, and ceremonial expenditures. Many of these expenditures are fairly large rel-

[2] The potential that larger farmers with higher profits and more favorable loan terms have for offering higher land bid prices is well established in the literature concerning U.S. agriculture. One well-known model for evaluating land prices is presented in Lee and Rask.

ative to the typical size of production loans and are not normally authorized uses of institutional credit. These circumstances give rise to the observed pattern and uses of noninstitutional loans and to a desire to divert production loans and household savings to these uses. Interest rates of 7% to 14% may be a small price to pay for fungible institutional loans if it helps the borrower escape scrutiny and monitoring of the friends and relatives who grant consumption and investment loans. However, there are always potential risks of discovery when diverting institutional loans. An even larger demand for such loans would likely emerge if the constraints on their use were relaxed.

What can we learn from these papers that contributes to the long-standing debate over the nature of rural financial markets in developing countries and the appropriate strategy to use in improving them? The China example reminds us that, if there are serious constraints in production inputs, there will be little demand for production loans. But if there are liquidity demands for consumption and investment, there will be a strong demand to divert fungible loans to these purposes. The greater the fungibility of institutional loans and the lower their interest rates relative to alternative sources, the more valuable they will be and the more likely will be the diversion of funds. Low interest rates lead to excess demand and nonprice rationing. This gives larger, more powerful farmers a reason to use their influence to get a larger share of the pie. It also gives rent-seeking loan officers an opportunity to extract bribes and other considerations from rationed borrowers. Borrowers who "buy" loans see little reason to repay them, so loan recovery is compromised along with the viability of financial institutions.

There is no question that getting an advantage in the credit market by obtaining a larger loan or better loan terms can translate into advantages in other markets. Access to loans and loan size are usually correlated with land ownership, particularly in underdeveloped formal financial systems. Therefore, inequalities in land are often at once the cause and the effect of credit market inequalities, as implied by Carter and Wiebe. This fact prompts policy makers to try to regulate financial markets so that certain groups, such as small farmers, gain greater access. But experience shows that this has been an ineffective policy, so equity concerns must be addressed more directly through interventions in other markets, especially land. The most that can be expected from the financial markets is that, through experience, lenders will learn to assess risks and returns correctly so that agricultural loans become part of their efficient portfolios.

It is also clear that regulation-induced distortions in financial markets, when a large volume of credit is involved, as was the case in Brazil, will greatly exacerbate existing inequalities and create distortions in resource allocation. There will be gainers and losers in the painful adjustment process following removal of such regulations. The cost of adjustment should be, but is not likely to be, part of the evaluation process when such regulations are considered in the first place.

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Rural Poverty among Racial and Ethnic Minorities

Joyce E. Allen and Alton Thompson

Historically, rural minorities in the United States have been economically and socially disadvantaged.[1] Their disadvantaged status has its origins in institutional racism, human capital deficits, and geographical concentration in persistently poor areas with a low tax base and consequently minimal capital to invest in improving their socioeconomic conditions (Bedics, Durant and Knowlton, Kuvlesky et al., Moland, Tienda). Over the past twenty-five years, their plight has improved largely because of dismantling of *de jure* segregation; higher educational attainment; growth in the national economy; and expansion of education, training, and public transfer programs (Durant and Knowlton, Moland, Rodgers and Weiher). Nevertheless, rural minorities continue to be disadvantaged relative to minorities in urban areas and to whites in rural areas (Jensen 1990, Lichter, Lyson). In this paper, we examine recent trends and patterns in the economic status of rural minorities. Our focus is on the two largest rural minority populations, blacks and Hispanics. Further, we analyze the effect of race on poverty status and the determinants of poverty among rural minorities. Last, we address the policy implications of these findings.

Measure of Poverty

Prior to analyzing poverty trends, it is useful to examine poverty in a conceptual framework. As Davis (p. 11) has pointed out, "the word poverty has assumed a multiplicity of meanings at different times and places." While it is generally agreed that poverty refers to the inability to obtain basic necessities required to sustain a minimally adequate standard of living, it is difficult to operationalize the concept. Measurement of poverty is important for two reasons: (*a*) to determine who is economically deprived in order to target assistance to those persons and (*b*) to monitor progress over time in alleviating economic deprivation. There are many ways of measuring poverty, none of which is perfect. Moreover, estimates of the poverty population and the characteristics of that population are sensitive to the measurement tool. The official poverty level, as defined by the federal government, is an absolute standard as opposed to a relative one. In 1988, a family of four was considered to be in poverty if its annual money income was below $12,092 (U.S. Bureau of the Census).

The current measure of poverty was officially adopted by the federal government in the 1960s during the midst of the "War on Poverty." It is based on food needs of households of varying sizes and composition. The 1955 Survey of Food Consumption conducted by the U.S. Department of Agriculture (USDA) revealed that families of three or more persons spent, on average, approximately one-third of their money income on food. Thus, analysts at the Social Security Administration multiplied the cost of the Economy Food Plan (the least costly of four food plans developed by USDA) by three to derive poverty thresholds. The thresholds have been updated annually for inflation. Although some revisions occurred in 1969 and 1981, the original measure of poverty has remained basically constant over time.[2]

The deficiencies in the current measure of poverty have been well documented (e.g., Davis, Morris and Williamson). The nucleus of the

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[1] The terms rural and nonmetropolitan (nonmetro) are used interchangeably throughout this paper to refer to localities outside Metropolitan Statistical Areas (MSAs), as defined by the Office of Management and Budget.

[2] The following changes were made in 1969: (*a*) poverty thresholds were indexed to the Consumer Price Index in lieu of the economy food plan, (*b*) threshold for farm families was raised from 70% to 85% of the corresponding threshold for nonfarm families. The 1969 changes resulted in an additional 1.6 million persons being classified as poor in 1967. The separate thresholds for farm families were eliminated in 1981.

original poverty threshold was the Economy Food Plan, a plan designed for short-term emergency use. Morris and Williamson (p. 18) report that "a family could not expect to maintain a nutritionally adequate diet by following this diet on a long-term basis." Further, when the poverty thresholds were developed, in-kind benefits were not a major proportion of total income packages. However, over the years they have grown in importance. Indeed, food stamp benefits and Medicaid payments totaled $43.4 billion in fiscal 1988 (Office of the President). Annual food stamp benefits averaged about $600 per participant in fiscal 1988 (U.S. Department of Agriculture). Yet, in-kind benefits are excluded when determining poverty figures because countable income includes money income only. Another problem is that the definition of income refers to pretax income and thus ignores mandatory payroll taxes which reduce the amount of earned income available for consumption. In addition, researchers (e.g., Morris and Williamson) suggest that income is underreported in some government surveys, which results in inflated estimates of the poverty population.

Two other weaknesses in the measure of poverty are noteworthy. Consumption patterns have changed over time, but the current measure of poverty is based on data that are thirty-five years old, even though more recent data are available. In particular, the average proportion of income spent on food has declined from about 33% to less than 20%, which indicates that a multiplier higher than three could be justified, thus raising the poverty thresholds. Another dimension of the measurement problem is that the poverty thresholds do not vary by residence, implying that the same amount of money is needed in urban and rural areas to avoid economic deprivation. Despite these and other limitations, the official definition of poverty is an appropriate measure when examining poverty trends, largely because it has not changed over time and alternative measures have not gained widespread acceptance.

Rural Poverty Trends and Patterns

Data from the U.S. Bureau of the Census show that progress was made from 1970 to 1980 in reducing poverty among persons living in nonmetropolitan areas (table 1). This holds true across race and ethnicity. However, the decline was greatest among blacks. In fact, the rate for blacks declined by 26% compared to 18.3% for Hispanics and 3.7% for whites. Nonetheless, a disproportionate number of rural blacks remained impoverished. From 1980 to 1985, rural poverty rates increased largely because of national and global economic changes which adversely affected rural-based industries (e.g., farming, timber, oil, gas, mining) (O'Hare).[3] The percent increase was largest for Hispanics (33.3%), followed by whites (22.8%), and blacks (9.3%). From 1985 to 1988, rural poverty rates ranged from 2.9 to 0.6 percentage points above the 1980 level, despite the robust economic recovery which followed the 1981–82 recession. In 1988, 40.3% of rural blacks, 34.9% of rural Hispanics, and 13.1%, of rural whites were poor. The relatively high poverty rates during the economic recovery (especially among minorities in rural areas) appear to raise questions about the adage that "a rising tide lifts all boats." Indeed, Danziger and Gottschalk argue that demographic factors and changes in the shape of the income distribution limit the effectiveness of macroeconomic conditions in reducing poverty.

While poverty rates have been incessantly high among rural minorities, some population subgroups have been affected more than others. Specifically, persons in families with a female householder (no husband present) have substantially high poverty rates relative to the rates for all persons in families (table 2). Moreover, the majority of dependent children (under age 18)

Table 1. Poverty Rates for Nonmetro Persons by Race and Ethnicity, 1970–88

Year	White	Black	Hispanic[a]
		(%)	
1970	13.2[b]	52.7	33.4
1980	12.7	39.0	27.3
1985	15.6	42.6	36.4
1986	15.1	42.3	38.2
1987	13.7	44.1	35.6
1988	13.1	40.3	34.9

Sources: U.S. Bureau of the Census, Census of Population, *General Social and Economic Characteristics*, various years. U.S. Bureau of the Census, Current Population Reports, Series P-60, various issues.
[a] Hispanic persons may be of any race.
[b] The 1970 figure for whites is from the 1970 Current Population Reports, whereas the 1970 figures for Blacks and Hispanics are from the 1970 Census of Population.

[3] Metro poverty rates also increased during this period. However, the increase was larger in nonmetro areas. For example, the nonmetro rate increased by 6.7% compared to 18.8% in metro areas. Further, by 1988, the metro poverty rate was only 2.5% above the rate reported for 1980. In contrast, the nonmetro rate was 3.9% above the corresponding rate for 1980.

Table 2. Poverty Rates for Nonmetro Persons by Selected Characteristics, Race, and Ethnicity, 1980 and 1987

	White		Black		Hispanic[a]	
Characteristic	1980	1987	1980	1987	1980	1987
	(%)					
Families	9.9	11.9	34.3	42.4	23.9	35.1
Female-headed	27.2	35.8	54.6	63.0	49.5	56.2
Children under 18	37.3	51.4	61.8	76.7	57.4	66.5
Children under 6	52.4	64.6	68.2	81.3	66.3	(B)[b]
Elderly (65 & over)	11.1	6.6	38.4	33.0	29.3	(B)
Unrelated individual	30.6	25.6	57.1	55.3	45.2	38.4

Sources: U.S. Bureau of the Census, Census of Population: 1980, *General Social and Economic Characteristics*, Final Report PC80-1, C1, United States Summary. U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 163, *Poverty in the United States: 1987*. Washington DC, 1989.
[a] Hispanic persons may be of any race.
[b] Base less than 75,000.

in female-headed families are poor. In 1987, three-fourths of rural black children and two-thirds of rural Hispanic children in female-headed families were poor. The corresponding figure for rural white children was 51.4%. The data show that poverty rates are highest for young children (under age 6).

A number of negative outcomes are associated with growing up in a female-headed family. Garfinkel and McLanahan observe: "About half of them [female-headed families] are poor and dependent on welfare. The mothers and children in such families also have poorer than average mental health and use a disproportionate share of community mental health services. Most important, perhaps, compared with children who grow up in two-parent (husband-wife) families, the children from mother-only families are less successful on average when they become adults. They are more likely to drop out of school, to give birth out of wedlock, to divorce or separate, and to become dependent on welfare."

Table 3. Educational Attainment of Poor Nonmetro Householders by Race, 1987

Education	White	Black
	(%)	
Less than 9 years	26.3	39.0
9–12 years	17.6	24.2
High school	41.5	31.4
1 year college or more	14.7	5.5
Median years	12.1	10.4

Source: U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 163, *Poverty in the United States: 1987*. Washington DC, 1989.

The literature also indicates that children from female-headed families are less likely than their counterparts in two-parent families to graduate from high school and are at increased risk of having low earnings and living in poverty. Further, several researchers have concluded that many of the negative outcomes are related to the extreme economic deprivation that exists in many female-headed families (Allen and Joshi).

Because stock of human capital of the householder is correlated with the household's poverty status, we examined data on one indicator of poor rural householders' human capital, their highest level of education (table 3).[4] Not surprisingly, a sizable proportion of poor rural householders have not completed high school, a finding which emphasizes their human capital deficiencies. Moreover, a substantially higher segment of blacks (63.2%) than whites (43.9%) were in this category. The data reveal that only a small proportion (5.5%) of poor rural black householders had at least one year of college. Some of the observed deficiencies in the human capital of rural blacks are probably the legacies of segregated schools in the South combined with a historic pattern of inadequate school financing. For example, Lyson has found that rural blacks and Hispanics are concentrated in counties with lower school expenditures compared to the expenditures in rural counties with low concentrations of minorities. He estimates that school expenditures were 17.8% less in rural counties with large concentrations (30%, or more) of

[4] Comparable data were not available from the Bureau of the Census on the educational attainment, work experience, and occupation of poor nonmetro Hispanic householders for 1987.

blacks and 12.2% less in those counties with large concentrations of Hispanics.

Human capital skills can influence employment opportunities and, thus, poverty status. Data from the U.S. Census Bureau show that a sizable proportion of poor rural householders are employed (table 4). For example, 42.9% of poor black rural householders were employed in 1987, but only 17.5% of them worked year-round (50–52 weeks). The proportion falls to 13.3% for those who worked full-time (35 hours or more per week) year-round. The dominant reasons that poor black rural householders did not work were illness or disability, keeping house, or inability to find work. Many of those who were keeping house likely were female householders with dependent children. For persons in this category, child care costs combined with limited human capital could mean that if they were employed, their earnings would not be sufficiently high to ensure improvement in their economic status.

Table 4. Work Experience and Occupation of Poor Nonmetro Householders by Race, 1987

Characteristic	White	Black
	(%)	
Worked[a]	58.6	42.9
1–49 weeks	32.8	25.4
50–52 weeks	25.8	17.5
Did not work	40.9	56.5
Main reason for not working:		
Ill or disabled	30.2	37.4
Keeping house	29.8	30.3
Going to school	3.6	3.6
Unable to find work	13.5	18.5
Retired	21.6	9.6
Other	1.6	.7
Occupation of longest job		
Managerial and professional	7.3	2.4
Technicians and related support	.3	1.9
Sales	9.0	7.0
Administrative support[b]	4.2	3.8
Private household service	1.5	4.7
Protective services	1.4	
Other services	17.2	37.1
Farming, forestry, and fishing	20.7	10.3
Precision production, craft and repair	16.5	8.5
Operators, fabricators, and laborers	21.7	24.4
Armed Forces	.3	

Source: U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 163, *Poverty in the United States: 1987*. Washington DC, 1989.

Note: Poverty status and work experience in 1987. Families as of March 1988.

[a] The Census Bureau includes members of the armed forces in the aggregate data on which work experience of householders is based but it does not report data on them separately. Thus, the percentages for worked and did not work do not total 100.

[b] Includes clerical.

Poor black rural householders who were employed were heavily concentrated in the following low-wage occupational groups: services and operators, fabricators, and laborers. Moreover, they held a narrower set of occupations compared to their white counterparts. This finding could reflect the nature of the job market in counties where rural blacks are heavily concentrated. For example, Lyson and Falk indicate that Black Belt counties are dominated by industries that are either slow growing, stagnating, or declining. Further, Bellamy and Parks found that Black Belt counties gained few or lost more manufacturing plants compared to non-Black Belt counties and tended to have more routine (i.e., low-wage) manufacturing.

Determinants of Rural Poverty

We used data from the March demographic file of the 1988 Current Population Survey, conducted by the Bureau of the Census, to examine determinants of rural poverty. The unit of analysis is nonmetropolitan families headed by a civilian. Table 5 presents a summary of the operational definitions of the variables used in the empirical model. Past studies (e.g., Thompson, Traub, and White) have found that several of these variables are important predictors of poverty. Based on previous empirical studies, we hypothesized that the following rural subpopulations will have a greater propensity to be in poverty: blacks, families headed by older per-

Table 5. Operational Definitions of Variables

Variables	Coding
Dependent variable:	
Poverty	0 = income at or above poverty threshold
	1 = income below poverty threshold
Independent variables:	
Race	1 = black; 0 = white
Age	Age (in years) of family head
Family type	1 = female head; 0 = other[a]
Family size	Number of persons in family
Region	1 = South; 0 = non-South
Education	Years of schooling of family head
Earners	Number of earners in family
Weeks worked	Annual number of weeks worked by head
Industry	1 = secondary; 0 = primary

[a] Other refers to families headed by a married couple or male householder with no spouse present.

sons, female householders, large families, Southerners, families headed by persons with low levels of education, families who have only one earner, families headed by persons who work a limited number of weeks during the year, and families headed by persons who are employed in the secondary sector.

Poverty status, the dichotomous dependent variable, is based on the federal thresholds. Most of the independent variables presented in table 5 are straightforward and require little explanation. One exception, however, is industrial structure. According to the dual labor market theory, some of the observed earnings and/or income differentials are related to the structure of the job market. Proponents of this theory (e.g., Averitt, Hodson, Tigges) argue that jobs can be divided roughly into two sectors, primary (monopolistic) and secondary (competitive). Firms in the primary sector tend to be large, diversified, capital intensive, and to offer high wages and opportunities along clearly defined career ladders. Conversely, firms in the secondary sector tend to be smaller, more labor intensive, more vulnerable to the vagaries of the labor market, and to offer low wages and limited opportunities for career mobility. Based on Hodson's industrial typology, we classified the following industries as constituting the primary sector: durable manufacturing; construction; transportation, communication, and public utilities; wholesale trade; finance, insurance, and real estate; public administration; and professional and related services. The secondary sector, in the model specification, consisted of nondurable manufacturing; retail trade; business and repair services; personal services (including private household); entertainment and recreation services; mining; and agriculture, forestry, and fisheries.

The logistic regression estimation procedure that we employed enabled us to assess the probability (or odds) of a person being in poverty as a function of a set of explanatory variables. The model is of the form:

$$\log(P(pov)/1 - P(pov)) = \alpha + \Sigma\, \beta_i X_i,$$

where α is the intercept term and β_i is the set of coefficients for the explanatory variables, X_i.

Equations (1)–(4) in table 6 contain the effects of the log-odds and odds for selected variables that we hypothesized would affect the probability that families in rural areas would be poor. The signs on the independent variables were as expected, with the exception of age of head

Table 6. Logistic Regression Models of Poverty Status: Nonmetropolitan United States

	Estimates For Models			
Independent Variables	Total Sample (1)	White Respondents (2)	Black Respondents (3)	Hispanic Respondents (4)
(Intercept)	5.81	5.08	7.00	4.22
Race	0.65			
	1.91**[a]			
Age	−0.04	−0.04	−0.04	−0.03
	1.04**	1.04**	1.04**	1.03
Family type	1.19	1.14	1.47	0.93
	3.28**	3.13**	4.35**	2.53**
Family size	0.46	0.45	0.66	0.53
	0.63**	0.63**	0.52**	0.58
Region	−0.07	−0.07	−0.09	0.59
	0.93	0.93	0.91	1.80
Education	−0.18	−0.18	−0.22	−0.09
	1.20**	1.20**	1.25**	1.09
Earners	−0.99	−0.89	−2.00	−1.11
	2.69**	2.44**	7.39**	3.03
Weeks worked	−0.05	−0.06	−0.05	−0.05
	1.05**	1.06**	1.05**	1.05
Industry	0.76	0.77	0.80	0.67
structure	2.14**	2.16**	2.23**	1.95*
Model X^2	1515.91	1216.80	210.78	93.17
R^2	0.29	0.26	0.37	0.22

Note: For each independent variable, two estimates are shown. The first value is the effects on the log odds, and the second value is the effects on the odds.

[a] Double asterisk indicates $p \leq .001$; single asterisk indicates $p \leq .05$.

and region.[5] To aid in interpretation, we transformed the log-odds to the odds by exponentiating the log-odds regression coefficients. Thus, we can determine the magnitude and relative importance of selected variables, including race, in accounting for poverty among families in rural areas. In the sections below, we focus primarily on the substantive magnitude of the odds coefficients. Variables described as significant were statistically significant at the 0.001 level, unless otherwise noted.

The results from equation (1) show that the most important variable in accounting for poverty among persons in rural families is family type. That is, persons in female-headed families are significantly more likely to be in poverty than persons in families headed by a married-couple or a male householder. The odds of persons in female-headed families being poor is 3.28 times higher than for other family types.

Number of earners, industrial structure, and race follow next in importance. As expected, poverty was a decreasing function of the number of family members who had earned income. The model results show that each additional earner in the family reduces the odds of being in poverty 2.69 times. Converting the odds coefficient to a proportional effect reveals that each additional worker decreases the probability of a rural family being in poverty by 6%. Another finding pertaining to the labor market indicates that families headed by persons employed in the secondary sector have a greater likelihood to be in poverty than those headed by a person employed in the primary sector. Specifically, the former group is more than twice as likely to be in poverty than the latter. Similarly, black rural families were nearly twice as likely to be in poverty compared to their white counterparts.[6]

Education of the householder, a proxy for the stock of human capital, had a modest, but significant, effect on the odds of a rural family being in poverty. Converting the odds coefficient to a proportional effect, each additional year of education decreased the probability of being in poverty by 1.5%.

Age of the householder and the number of weeks that he or she worked had meager effects on the probability that rural families were poor. The odds coefficients for these variables were almost 1:1 (even odds). The direction of the relationship shows that the probability of being poor decreased modestly with age and the number of weeks worked. Family size and region had the smallest effects on the odds that rural families were poor. Specifically, the probability of a rural family being in poverty increased with family size; each additional family member increased the odds of being in poverty by 0.63, holding other factors constant. Further, rural families in the South did not exhibit a greater likelihood of being impoverished than their counterparts in other regions of the country.

As shown above, the race differential in the probability of being in poverty was relatively substantial. Equations (2) and (3) provide information on the nature of these differences as reflected by the magnitudes of the coefficients. In addition, equation (4) provides comparable information for persons of Hispanic origin. Without exception, the coefficients for white families mirror those for all families. A salient finding for the black respondents, however, is that the number of earners in the family contributed substantially to the likelihood of being in poverty. Holding other factors constant, each additional family member who had earned income was estimated to reduce the odds of being poor by 7.39 times. This odds coefficient has, by far, the largest magnitude of all the variables in the four equations. Moreover, it was three times larger than the corresponding odds coefficient for the white respondents (2.44) and nearly two and one-half times larger than the odds coefficient for Hispanics (3.03). A second salient finding for the black respondents is the importance of family type. The odds of a rural family headed by a female being poor is 4.35 times greater than for families headed by a married couple or male householder. The corresponding odds coefficients for the white and Hispanic families were 3.13 and 2.53, respectively.

The number of earners and family type were the two variables that contributed most appreciably to the probability that rural Hispanic families were poor. This was the same pattern observed for whites and blacks. However, there were some ethnic differences in the nature and magnitude of the odds coefficient for region. Rural Hispanics living in the South were 1.80 times more likely to be in poverty than their counterparts in other regions. This finding was significant at the 0.10 level.

[5] In some preliminary models, age of family head was specified as a quadratic variable. However, it was not statistically significant in these models.

[6] Because of the small number of Hispanics relative to non-Hispanics, the ethnicity variable was dropped from the model. Inclusion of that variable would have resulted in an unreliable log-odds coefficient for ethnicity. In fact, SAS LOGIST procedure would not generate the coefficient.

The substantial similarity of the odds coefficients for the remaining five variables—age, family size, education, weeks worked, and industry structure—show that the racial and ethnic differentials were minimal. Although, the magnitudes of the coefficients were different for blacks and Hispanics, the rank order of importance for the variables included in the model were identical.

Policy Implications

The findings in this study have implications for public policies that are designed to ameliorate poverty among rural minorities. As shown above, family type is an important determinant of rural poverty. Because many female householders with dependent children are not employed, they rely heavily on Aid to Families with Dependent Children (AFDC) benefits for income. In the South, where rural minorities are concentrated, AFDC benefits are typically low. For example, the maximum monthly benefit in Mississippi for a poor family of three was $120 in 1989 (U.S. House of Representatives). Thus, policies that would be beneficial to poor rural minority female-headed families include (*a*) raising the level of AFDC benefits and (*b*) assisting female householders to enter the labor force. For many of these householders, affordable, reliable, quality child care would be a necessity. Expansion of the Child Care Tax Credit could assist female householders because it would provide additional financial assistance for work-related child care expenditures. Because Congress has passed legislation this year to expand child care tax credits and the Bush administration has also proposed legislation in this area, it appears likely that some expansion will occur in the near future. However, given the current budget deficit, the tax credits are unlikely to be expanded sufficiently to have a large effect on rural poverty among female-headed families with dependent children.

The results from the model show that regardless of human capital, industrial structure has a substantially significant effect on rural poverty. This finding has implications for job creation strategies. If rural poverty is to be reduced, *ceteris paribus,* then the bulk of jobs needs to be created in the primary rather than the secondary sector. Otherwise, a large proportion of rural persons would be among the working poor because their earnings would not be sufficient to lift themselves and their families out of poverty. However, rural areas are at a competitive disadvantage when seeking primary industries, in part the result of deficiencies in the human capital of their population.

Although improvements are needed in the human capital skills of rural minorities, the fact that they are heavily concentrated in economically disadvantaged areas implies that local resources may not be available to support needed improvements in the quality of education. Thus, school financing issues are critical. It is important that state governments address inequities in school financing. Recent lawsuits in Texas and Kentucky have focused attention on the effects of linking school financing primarily to local resources in those jurisdictions where poverty is pervasive. School financing, based on the wealth of the entire state, could help upgrade the human capital of rural minorities.

The logistic model revealed that race is an important determinant of rural poverty. Based on this finding, we suggest that equal employment policies combined with enforcement of civil rights laws are critical strategies for alleviating poverty among rural blacks. These efforts should also be beneficial to rural Hispanics.

In conclusion, the policies cited above are vital to help ameliorate poverty among rural minorities. Some (e.g., human capital development, job creation) could be important elements of a comprehensive rural development program. Rasmussen contends that the first rural development efforts (e.g., improving physical characteristics of rural areas—roads, electricity, et cetera) met with quick and quantifiable success but that unemployment, persistent poverty, and inadequate housing may be more intractable. Indeed, these conditions which disproportionately affect rural minorities are the challenges that policy makers face in the 1990s.

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The Impacts of Structural Change and Public Policy on the Rural Disadvantaged

Ralph D. Christy and Enrique E. Figueroa

The social and economic consequences of technological and institutional change in U.S. agriculture have untold and largely unrecorded impacts on economically disadvantaged ethnic minorities in rural America. Over the past few decades, we have witnessed rapid economic transformation in agriculture and in rural communities. One of the most important characteristics of rural America during the 1980s has been the upward trend in the poverty rate. Census Bureau data from 1987 indicate that 16.9% of people living in nonmetropolitan areas had incomes below the poverty level, up from 12.6% in 1970. The national poverty rate was 12.5% in 1970 and 13.5% in 1987. Poverty rates were especially high among racial and ethnic minorities. For example, the poverty rate was 44.1% among blacks and 35.6% among Hispanics residing in nonmetropolitan areas (U.S. Census 1987).

Put succinctly, the argument does not favor the use of technologies and institutions to retain a larger-than-necessary segment of our population in agriculture. At best, multiplier effects from agriculture are much lower than other economic activities that are industrial or manufacturing based. As a result, agriculture's major contribution to an economy is to "free-up" labor and resources to advance urban, industrial, and service-based economic development. Our concern with the transformation that occurred in agriculture, however, is that the disadvantaged—particularly ethnic minorities—who were spun out of agriculture were not adequately re-equipped to contribute to a changing economy for a number of reasons, including lack of equal opportunity and premarket and labor market discrimination. This situation now meets us head on; for, if the national statistics are correct, by the year 2000, three-out-of-five new entrants in the work force will be nonwhite. This projection spells potential problems for a country finding itself drawn closer to a global economy where efficiency, comparative advantage, and competitiveness rule the day, and that, for several reasons, has not invested sufficiently and wisely in its human resources. Therefore, for the first time in the nation's history, a situation exists where what is good for the country coincides directly with the interest of minorities (Wharton).

The objective of this paper is to focus on the relationships between technological and institutional change and the human capital needs of minorities in rural America. Specifically, this paper seeks to (*a*) review human capital theory in the context of a framework for analyzing economic change in agricultural and rural societies, (*b*) provide examples of the minority experience under structural adjustments in agriculture, and (*c*) offer some policy prescriptions for professional considerations. This paper is organized in sequential order under these three headings.

Theory of Change and the Role of Human Capital: An Evolutionary Approach

Institutional or evolutionary economics offers a framework which seeks to explain change. It alleges that a useful classification of the fundamental forces which influence the economic process consists of technology, institutions, resources, and people. These separate influences, and the interaction between them, provide a useful conceptual framework to study the impacts of technological and institutional changes on minorities in rural areas. Neoclassical economics has come under attack as a useful framework in policy analysis and social change because the theory purports to seek equilibrium as

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opposed to explain change; the assumptions are unrealistic and too easily violated (Hirshman), and policy analysis of social and economic problems requires multidisciplines (Bonnen).

The Theory of Change

The theory of change operationalizes the four driving forces as follows: according to Gordon and Adams, technology refers to the capabilities that people possess for improving their material welfare and for performing tasks in ways that involve less effort or are more effective. Technology is central to the basic tenets of institutional and neoclassical economic theory. To an institutionalist, the economy is influenced by an ongoing, cumulative, dynamic technological change as opposed to the view that an economy is driven by a desire of individuals for monetary gain (invisible hand). Institutional economics treats profit-seeking conduct as one of several institutionalized behaviors, not the only influencing force in society. Institutions represent the constellation of rights and duties that determine domains of choice for individual members of society. Humans, with their evolving biology, are the actors who manage the technology and the participants who form institutions that are subject to the constraint imposed by resources. And the final ingredient in influencing economic change is resources. In broad terms, resources include the whole physical and energy content of the universe (Gordon and Adams).

The theory of change is expressed as the interaction between changes in technology, institutions, humans, and resources. The institutional theory of change views technology as a primary and dynamic element in an economic process. Gordon and Adams write: "Monitoring all these interrelations are individuals, who are what they are in terms of physique and behavior as a result of their evolving biology and the impact of the evolving interaction of knowledge, institutions, and resources upon them. Also, the institutions of society are monitoring the individuals and constraining their behavior. Technology and resources, and individual biology, are evolving and interacting and conditioning individual attitudes and behavior. All this involves an ongoing, mixed-up process."

For example, a change in technology requires individual and institutional change. Likewise, change in institutions influences the behavior of humans and informs organizational performance.

Human Capital Development

The economics of human capital was introduced by T. W. Shultz with the publication "Investing in Human Beings" (Blaug). Later, Becker, in *Human Capital*, put forth a new theory by viewing improvements in humans as an investment (i.e., capital investment) in contrast to a consumption activity, particularly as it relates to post-secondary education. This research coincided with the early developments of the "War on Poverty" and, as such, much of the thinking of that time was incorporated into the policies and programs directed toward human capital development of the poor. Therefore, research was directed toward answering the question: Does the program make a difference? This research focused little on the interaction between technology, institutions, resources, and human capital.

In pursuing this question, the neoclassical debates of economics drew researchers to the examination of the relationships between educational inputs and dimensions of expected outputs. Thus, educational production functions took the form

$$Y = f(x_1, x_2, x_3 \ldots x_n),$$

where Y is test scores, earnings, or economic development; and X_1, X_n are vectors of inputs to include expenditures, teacher quality, physical plants, etc.

As a result, we have a body of economic research that uses alternative measures of outputs and different measures of inputs in an effort to identify and understand the factors contributing to improved educational results.

Now, before drawing out some of the major findings, it is important to understand some shortcomings that are inherent to the framework (i.e., production function) and to the nature of the problem being addressed (data, measurement and operational). Nevertheless, by drawing on several review articles and key research, insight is provided on the relationship between educational inputs and test scores, earnings, and economic development.

Test Scores

Much of the initial work applying the educational production function approach to the explanation of test scores was directed to the gap between the scores of minority students and white students. The use of test scores as a dependent

variable was an attempt to evaluate schools' performance. This approach, despite its limitations, has provided some consistent findings important to educational policy makers (Hanusheck). (*a*) Differences in family socioeconomic background lead to significant achievement differences. (*b*) Differences among schools and teachers are important in explaining differences in achievement. (*c*) Differences by race (family background) interacting with school resources influence achievement. Hanusheck points to a number of uncertainties. Given the contradictory results of the studies and measurement problems, the effect of school quality, peer compositions, and dynamics of the educational process of achievement are not clearly understood.

The policy implications of studies evaluating achievements, particularly as they relate to minorities, centers around the effectiveness of compensatory education (i.e., Head Start) aimed at preparing preschool students for school (Title I of the Elementary and Secondary Education Act of 1965) and improving the achievement of disadvantaged children in elementary schools (measured by standardized test scores). Mullin and Summers concluded that the programs have a positive, though small, effect on the achievement of disadvantaged students. Sawhill summarized the results of this research as: (*a*) I.Q. gains are large in the immediate post-program period but vanish over time. (*b*) Some measures of school success, such as normal grade progression and not being required to attend special education classes, remain positive throughout the follow-up period. (*c*) The evidence for other indicators of scholastic achievement is mixed. (*d*) Three studies found lower high school dropout rates among participants.

Earnings (Income)

A fundamental assumption for investment in education, influenced by the human capital literature, is the existence of a positive relationship between educational levels and earnings. In the aggregate, the positive relationship between expenditures on human capital and earnings should reduce poverty rates among targeted groups.

What does the evidence suggest? According to Sawhill, the ability of human capital programs to increase productivity and earnings has been varied, primarily because of research design problems. Little is known as to why specific programs work. Do education and training actually increase productivity, or do they simply give people credentials or access to mainstream labor markets that helps them to land jobs? Drawing on survey literature, Bassi and Ashenfelter conclude that employment and training programs have been neither an overwhelming success nor a complete failure in terms of their ability to increase the long-term employment and earnings of disadvantaged workers. Major results of training programs are: (*a*) Positive results for adult women linked to job search skills that aid women entering the labor market. (*b*) No consistent findings of a significant effect among adult men. (*c*) Youth programs (i.e., Job Corps) are effective in enhancing incomes.

Research that focuses directly on educational and training programs in rural areas is limited. Huffman concluded that the lower productivity of black farmers is undoubtedly one of the factors contributing to the exodus of black farmers from southern agriculture at double the rate of white farmers during tthe 1950s and 1960s when agricultural technology was changing rapidly. This study highlighted the differences in educational levels between black and white farmers and the influence of extension service and research programs of land grand universities (1862 and 1890), given the historical discrimination practices of the region.

Economic Growth and Development

The empirical or statistical evidence supporting the relationship between human capital and economic development is not as robust as the case linking education to test scores and individual incomes. Economic development is an ongoing process and a more complex concept than the relationship between test scores and income. Economic development encompasses the process which an economy undergoes in transforming itself from a rural, agricultural based economy to an urban industrial-service-based economy. Schultz (1961) made this observation in attempting to link education to economic growth. "The connection, however, between education and economic growth is exceedingly complex. It is far from easy to identify those fruits of education that consist of improvements in the capabilities of a people that are useful in economic endeavor. It takes years as a rule to develop these capabilities and then it requires more years for these capabilities to prove their worth in production. It is not as simple as adopting hybrid seed corn or applying a few bags of

fertilizer in the spring and garnering the crop in the fall" (p. 47).

A region of the United States where questions of human capital and economic development are frequently posed is the rural south (Swanson). Education reform is seen as a strategy to obtain economic development within the region (Deaton and Deaton). Skees and Swanson conclude that the single most important factor associated with the well-being of rural communities is the level of education among the adult population. They note a striking consistency among the counties in Kentucky with low levels of adult education and median family income; these counties have the highest unemployment and underemployment and poverty. Generally, research suggests that human capital development is a necessary but not sufficient requisite for economic development.

Institutional Implications of Human Capital Development

Much human capital research has involved the application of neoclassical economics with the appropriate statistical and production function methods. Institutional research in the human capital development literature is not as well developed. However, a parallel exists between production economics and institutional economics, which has a focus on prescribing and predicting outcomes derived from alternative institutional arrangements (Schmid). Schmid draws this parallel by suggesting that one may seek to explore the effect of alternative institutions for human behavior in a similar way production economics attempts to explore the effect of alternative inputs on different levels of output. This type of inquiry is concerned with the question: Do alternative institutions make a difference?

Research using the so-called education production functions have attempted to link selected inputs to levels of output measured in terms of test scores, income, or economic development. The institutional approach seeks a link between alternative institutional arrangements (i.e., teacher training, capital improvements, administration) and the behavior of the individuals seeking human development. For example, institutional research may want to analyze the relationship between the organizational structure of school and learning attitudes, value of knowledge, and peer influences. Note two fundamental problems from this approach: because they are often case studies, the research focuses upon given attributes of schools and the learning process; and, second, they consider the relationship between a particular attribute and student outcomes to the exclusion of the possibility of interactions of inputs and exclusion of other attributes. Nevertheless, the production function approach provides policy relevance to the research efforts by drawing attention to the effects of inputs—student characteristics, teacher and school inputs—on the performance of the school system.

The broader question—How to capture the interrelationships between technology, institutions, resources, and human capital?—has particular implications for minorities in agriculture and rural society. The examples of the impacts of structural change and public policy on selected rural disadvantaged groups will provide insight into how changes in technology and institutions bear major consequences that are often detrimental. These relationships have in the past been largely outside the policy and research debates of our profession.

Structural Change and the African American Farmer and Rural Resident

Since, the early years of our nation, the role of the African American in the agricultural economy has been influenced by a series of institutional and technological changes that have transformed society profoundly, frequently placing this minority group in a precarious position. (This section draws on Johnson et al.) Both institutional and technological changes have played major roles in the transformation of agriculture and rural society; however, the consequences of these changes for the African American have been little understood (or understood perhaps too late) and up to now have received a low priority on social science research and public policy agendas. Several factors may account for the lack of information on the African American in rural society: (*a*) research programs, because of recent federal legislation, are relatively new to 1890 institutions, (*b*) ill-conceived and conflicting public policies, and (*c*) disparity in economic growth across regions in the United States.

The total number of nonwhite farms declined by 91% from 481,601 in 1954 to 44,640 in 1987. White farms declined by 48% from 4,301,420 to 2,240,976 during the same time period. Thus, nonwhite farms disappeared at almost double the rate of white farms. Nonwhite farms declined by 94% compared to a 56% decline for white

farms between 1954 and 1987 in the South, a region where the majority of African American farmers exist. Further, nonwhite farms in 1954 accounted for almost 20% of all farms but by 1987 they accounted for only 3.0% of all southern farms.

Since 1910 the amount of land owned by African American farmers has steadily decreased, with the exception of the period from 1940 to 1950. During that decade, under the prosperous conditions of the war and immediate postwar period, there was a growth in both the number of African American farmers who owned land and the amount of land owned. Hall reports that the peak period for minority-owned land was in 1920 when 13,949,000 acres were controlled by African Americans. By 1987, 22,954 African American owned farms held 2,636,896 acres of land, representing a new loss of 11.3 million acres of land. The amount of land owned by African American farmers continued to be proportionately less than land operated by white farmers. Several factors contributed to the decline of African-American-owned U.S. farmland, including credit policy, rural education, and intergenerational transfers.

The analysis of the impact of the fundamental changes occurring in rural America on the African American must consider demographic realities. Over 90% of U.S. African Americans resided in the South at the turn of the century and, despite the tremendous outflow of African Americans from the rural south, the southern region of this country contains more than half of the U.S. African American population (Lichter and Hester). More important, Lichter and Hester further observed that well over 90% of all nonmetropolitan blacks resided in the South. Therefore, an analysis of the social and economic well being of the rural African American should focus on the development of the rural South.

Increments in the poverty rate have been a major concern. In some counties—particularly in the South—poverty persists. A county with persistent poverty has had per capita income in the lowest quintile, i.e., the lowest 20% in terms of per capita incomes among counties in the United States for at least three decades (Bellamy and Ghelfi). These counties are characterized by low educational levels, poor health (physical disabilities), and a high percentage of African Americans in their population. Bellamy and Ghelfi note that poor counties have lower per capita income than those counties which improved between 1979 and 1984. Understanding the evolving characteristics of these counties may suggest policy alternatives for enhancing the socioeconomic conditions of their residents.

Institutions and technology are fundamental forces giving rise to the changing structure of agriculture and the status of rural communities. Understanding how these changes have influenced the economic well-being of African Americans is a challenge for policy makers and professional economists. This paper argues that institutional and technological forces have demonstrably placed African Americans, partly because of the lack of human capital development, in a precarious position. African Americans, as a group, still earn lower incomes (Smith and Welch), are three to four times more likely to experience poverty in rural areas, and have exited agriculture at twice the rate as their white counterparts. The decade of the 1980s has also witnessed deterioration in the educational progress of African American youth at the high school (Jaynes and Williams, p. 334) and the college levels (Carter and Wilson). This knowledge becomes more alarming when one considers the fact that the economy is in the midst of another major transformation—information-service age (Eitzen and Zinn). Given the growing importance of the minority population within this country, much is needed to further develop our understanding of the impacts of the forces in this new economic environment and putting in place the appropriate research, outreach, and policy responses.

Immigration Policy and Hispanic Labor Issues

The passage of the Immigration Reform and Control Act of 1986 (IRCA) brought a new set of policy and institutionally related issues with particular importance to Hispanics in the United States. Included are the following issues: the impact of employer sanctions on discriminatory employment practices against Hispanics; impact on the wage rate of native and newly legalized Hispanics (a significant number of IRCA-legalized individuals are Hispanics, as are native individuals vying for the same jobs as the newly legalized); impact on the viability of industries that historically have utilized illegal workers (agriculture being one); regional impacts of labor availability which may place perishable agriculture commodity production at high risk; impact of an expanded H2-A program on native and IRCA legalized Hispanics; and the eco-

nomic impact on communities with high concentrations of native Hispanics and IRCA-legalized individuals. Though the consideration and passage of IRCA as well as the IRCA mandates generated a number of research papers, a clear concensus on the policy implications has yet to surface. Given that Hispanics—native, IRCA-legalized, and undocumented workers—comprise a significant percentage of the labor pool for seasonal agricultural labor, the policy issues have particular relevance for the perishable products sector of agriculture. In the remainder of this section, the above issues are expanded and examples of past relevant research are presented.

Rochin and de la Torre identify a broader set of issues pertinent to Hispanics in rural America as well as relevant demographics. By the turn of the century, Hispanics will number nearly 29 million and reside predominantly in California, Texas, New York, and Florida. Rochin, Santiago, and Dickey present an historical analysis of the contribution of individuals of Mexican decent on Michigan agriculture. Their conclusions indicate that farm mechanization has not removed the need for seasonal labor, that labor-intensive production enterprise is increasing, and that a need exists for addressing the problems specific to the Hispanic component of the labor force in Michigan.

Employer Sanctions and Employment Discrimination

Employer sanctions require that employers verify the legal status of all employees. If an employer employs undocumented workers, then he/she will be warned, fined, and can eventually be incarcerated if violations continue. To preclude possible discriminatory (against "foreign-looking" individuals) practices by employers, IRCA mandated an analysis of the impact of employer sanctions on discriminatory hiring practices. The General Accounting Office (GAO 1990) found that widespread discrimination did exist and some of the discrimination was a result of IRCA; however, the component of total discrimination attributed to IRCA was difficult to quantify. The need exists for broader and more rigorous analysis of the economic impact of discrimination, particularly on Hispanics. Also, if employer sanctions are repealed because of adverse discriminatory effects, what impacts will this outcome have on the availability of illegal workers in agriculture, on wage rates, on rural communities with high concentrations of Hispanics, and on the viability of agricultural producing regions?

Wage Rate Effects

How will IRCA affect the U.S. agricultural labor market, particularly supply response? Few studies exist that can provide a basis for answering the question. Emerson found that both demand and supply of local harvest labor are inelastic, that migratory labor supply is more elastic, and that labor markets are linked across seasons. Also, free trade would lead to increased/decreased migration from Mexico to the United States during the winter/summer, and guest worker programs lead to losses for domestically owned factors of production. In short, migratory labor has not fared as well as domestic labor, and guest workers adversely affect domestic workers. Torok and Huffman found the elasticity of U.S. demand for apprehension of undocumented workers with respect to the Florida agricultural wage rate was −2.05; the elasticity of U.S. demand for apprehension of undocumented workers with respect to the real price of Florida tomatoes was +.05; and the elasticity of U.S. demand for apprehension of undocumented workers with respect to the U.S. unemployment rate was −0.47. The U.S. demand for apprehensions of undocumented workers decreases as the Florida wage rate increases and, therefore, relatively more undocumented workers enter the labor force, which in turn exerts downward pressure on wages. As Florida tomato prices increase, the demand for apprehensions increases, which in turn serves to decrease the supply of harvest labor. This outcome may curtail tomato supply and therefore contribute to high tomato prices. Emerson, Walker, and Andrew found a domestic citrus-harvest labor-supply elasticity of 6.45; an elastic effect of income opportunities outside the citrus industry on the supply of citrus harvest labor of +1.09; the importation of harvest workers negatively affects the wage rate of harvest labor; off-shore (H-2) workers reduce the employment opportunities of domestic workers; and government policies have not represented the best interests of domestic labor. The large supply elasticity of citrus labor is inconsistent with the inelastic supply cited at the beginning of this paragraph; but the inconsistency is because the former concerns itself with local labor, whereas the latter is for migrants. If one argues that IRCA has diminished mig-

rancy, then this outcome will exert upward pressure on wages if labor supply decreases. Last, the 1988 GAO study found that illegal workers in agriculture do exert downward pressure on wages received by domestic workers and that seasonal agricultural services crops (SAS) have not suffered production declines because of their historical reliance on illegal workers.

Domestic citrus pickers, many of whom are Hispanics, would receive higher wages if the IRCA were successful at stopping the hiring of illegals. However, if preventing the hiring of illegals includes discriminatory hiring practices against Hispanics, then the net result is ambiguous. The apprehension of illegals by the Immigration and Naturalization Service has acted to sustain higher prices for Florida tomatoes, alleviated excess demand for harvest labor, and exacerbated unemployment. These outcomes require careful attention and analysis.

Regional Impacts of Labor Availability

Most of the seasonal agricultural workers (SAWs) legalized under IRCA were from California, roughly 70%. The IRCA-mandated quota for replenishment of agricultural workers (RAWs) for fiscal year 1990 was zero. RAW's are workers that can be admitted into the United States if they work at least ninety days in SAS crops. After three years, RAWs can then apply for permanent residency. The zero quota for RAWs is difficult to analyze. It has a positive effect on domestic and IRCA legalized Hispanics because fewer individuals will compete for jobs; however, for this to be true, one must assume that H2-A workers will not be imported and employer sanctions will be strictly enforced. A priority preference for RAWs was afforded to family members of SAWs. Therefore, the potential for families to be unified was diminished by the zero quota.

Related to this topic is how regions in Mexico have been impacted by IRCA. Ranney and Kosesoudji provide an assessment of remittancs by Mexican residents who worked in the United States—$55.00 per week—whether they paid taxes (50% did) and Social Security (67%) and found that 50% worked in California and 33% worked in Texas. Warren and Passel provide a regional distribution of illegals in the United States, and White, Bean, and Espenshade present an analysis of undocumented migration in the United States. Much remains to be done about regional "push-pull" factors, the differential impacts of national policy on communities with clusters of Hispanics, and analysis of the economic gains/losses of future distributions of RAW quotas.

Expanded H2-A Program

In 1986, 21,177 workers were certified by the U.S. Department of Labor (DOL) as H-2s—47.5% worked in Florida in the sugarcane industry, 30.1% in the apple industry (13% in New York, 7% in Maine, and 7% in Virginia), and the rest in various other agriculture industries. A critical component of the program is the wage rate that H2-A workers will receive. GAO (1988) found serious flaws in how DOL determines the appropriate wage rate and concluded that the estimates were highly imprecise. It found that the presence of foreign workers depresses wage rates and that the prevailing wage rate, when estimated in areas where foreign workers are or have been, does not provide an accurate reflection of the prevailing wage rate. The H-2A program impacts on Hispanic workers by depressing agricultural wages and by curtailing the demand for domestic agricultural workers. As recommended by GAO, it is imperative that new methodologies and procedures be developed for ascertaining the adverse wage effect and its effect on the availability of domestic labor. Without these efforts, Hispanic agricultural workers will continue to face adverse economic conditions.

Economic Impact on Communities

IRCA's impact on communities with high concentrations of Hispanics—principally in California, Texas, and other southwestern states—is an important and virgin research arena. From an income perspective, Sehgal's work provides illuminating evidence on the impact on a community. In her sample of foreign-born individuals, she found 7% of Hispanic households, 30% of Asian, 17% of white, and 30% of African American households had annual incomes greater than $35,000. The comparable figures for native born individuals were: Asians (26%), whites (20.5%), African Americans (17%), and Hispanics (11%). The level of education of both foreign and native born individuals appears to be responsible for the income differentials. One can surmise that establishing citizenship for Hispanics increases the potential for their educa-

tion, particularly for their offspring. Similarly, Rochin found that a number of Chicano farm worker cooperatives did not succeed because of the poor training of individuals managing the cooperatives.

Several communities have high concentrations of Hispanics. Presley points out that currently 6.6 million Latinos live in California and, by 2030, 14.8 million Latinos are expected to reside there. The following quote from Presley succinctly addresses the challenges ahead for individuals interested in public policy issues pertinent to Hispanics. "Studies are needed of the implications of immigration, particularly in light of IRCA, for health, education and other public services: the social organization of the immigrant communities in California and the impacts of emigration upon the foreign sending communities; the effects of IRCA on jobs and the restructuring of the labor market, especially in the agricultural sector, and ways to help California firms adjust to these changes and to comply with the law."

Conclusions

For a society that has transformed from a rural to an industrial-service based economy, the drive to maintain some comparative advantage in food production is reasonable. But this economic development process also requires the need for helping individuals make the transition. Thurow states that "the failure to aid in this transition is the central failure of current agricultural institutions and arrangements" (forthcoming). Many argue that our profession is unwilling to tackle the broader socioeconomic policy issues of our time. Bromley writes, "The focus seems to remain—for the most part—on tinkering with different support programs to ameliorate the strong production incentives that they create" (forthcoming). The problems of concern in this paper require a broader perspective than economic adjustments within the agricultural sector alone. As the divergence between agriculture and rural communities becomes more apparent, so will the linkages between some contemporary urban problems and challenges to rural communities.

Many segments of rural America are responsive to major sectorial shifts and macroeconomic changes which act much as a tide—when the tide waters are high they lift all boats and vice versa. However, there is growing evidence that a persistent group, the disadvantaged, is a visible component of our society; and this subset, for the most part, seems to be immune to aggregate social and economic forces. Wilson defines the underclass as "that heterogeneous grouping of families and individuals who are outside the mainstream of the American occupational system. Included . . . are individuals who lack training and skills and either experience long-term unemployment . . . and families that experience long-term spells of poverty and/or welfare dependency" (p. 8). To date, little is known about the complex causal links among economic conditions, family structure, and individual or group values.

Conversely, it is commonly recognized, that individuals experiencing poverty are generally less educated and exhibit unstable employment histories. Future policy directives important to disadvantaged minorities in rural America must be given priority if the United States is to remain competitive. Several elements of a public policy agenda that can meet the needs of the disadvantaged are offered and they need to be specific so as to redress this situation.

Public policies in agriculture and rural areas have had differential impacts on ethnic minorities. Some of these impacts have been very detrimental, principally because of the lower levels of human capital. Policies directed toward helping minorities make the transition were slack, and many families have remained in poverty for several generations in both rural and urban areas. Specific policies are needed to redress this situation.

Programs associated with agricultural policies were operated in a manner that has further widened the gap between disadvantaged groups and the rest of the population of rural America. This occurred for several reasons, including the fact that program administrators discriminated against ethnic minorities, the lack of political influence by the rural disadvantaged, and the unavailability of clear and simple information about program objectives and procedures. Programs must consider alternatives that will take into consideration these shortcomings.

Human capital development has the effect of increasing not only individual incomes; but, in a rapidly changing economy, it also increases individual mobility. Education has historically been a state and local government responsibility. Because the U.S. economy is rapidly transforming, additional federal support should be given to human capital development programs to meet the demands of a rapidly changing economy.

Finally, the large unemployment rates among

the disadvantaged and ethnic minorities calls for an expanded role of government in the creation of jobs, particularly in the public service arena. Evidence from previous human capital development programs suggests that employment opportunities along with training will lead to the desired level of participation in the economy by disadvantaged individuals. As the economic organization and public policy environment change, rural development policies must adapt to the changing economic and social conditions to encourage an economic development that will reach disadvantaged groups.

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Human Capital, Economic Development, and the Rural Poor: Discussion

Refugio I. Rochin

It is a pleasure for me to comment on the two papers presented: one by Allen and Thompson ("Rural Poverty Among Racial and Ethnic Minorities") and the other by Christy and Figueroa ("The Impacts of Structural Change and Public Policy on the Economic Well Being of the Rural Disadvantaged"). Both papers complement each other nicely by focusing on the often neglected disadvantaged populations in rural America and the possible correlates or "determinants" of rural poverty. They also bring to light much needed information on rural African-Americans and Hispanics. These two groups, with the possible exception of Native Americans, face the highest incidences of rural poverty in the United States today, and their situation is worsening. The papers are also timely and important, especially with regard to emerging national demographic trends. The major trends affecting our rural economy have been reported regularly in the *Monthly Labor Review*. According to the Department of Labor, by the year 2000 we will have several challenges related to matching the supply of labor with the demand for labor. Of note: (*a*) There will be relatively fewer new workers from the traditional labor pool of white males. (*b*) White male workers will be relatively older and probably in the top positions, with few in the lower rungs of industry. (*c*) There will be more women, more minorities, and more immigrants entering the labor force, and their resumés will be vastly different from those of white males. They will have problems of child care and schooling. (*d*) Most new jobs will be in service and information industries, and all new labor force entrants will face fewer jobs in manufacturing and retail trade. (*e*) New jobs will require higher skills but not necessarily higher education.

The challenges for employers will be immense. They will have to adjust to the fact that women and minorities are going to reshape the American workforce, that new minority and immigrant entrants to the labor market will outnumber new white entrants by three to two, and that one in every three U.S. residents will be nonwhite by the year 2000. Rural America's future will not be immune to these trends. Both farmers and rural employers will have to be increasingly concerned about competing for more minorities and women. Employers will be indirectly involved in issues of the disadvantaged, in recruiting and accommodating more persons of diverse backgrounds into their workforce.

I would like to comment now on the paper by Christy and Figueroa because they give us clues as to how these demographic trends are affecting rural America and how we should study these trends. To begin with, Christy and Figueroa remind us that rural workers have been traditionally mobile workers who eventually leave agriculture for urban areas and until now have been historically displaced in line with general changes in farm size and structure. They also point out their concern with the rural disadvantaged, particularly ethnic minorities, "who were spun out of agriculture and were not adequately re-equipped to contribute to a changing economy for a number of reasons—including lack of equal opportunity and pre-market and labor market discrimination." I agree with that concern, but I believe that the new demographics portend a situation that will result in a need for rural institutions and rural employers to become more wary of unchecked local labor displacement. That is, if the demographic forecast unfolds, then the rural economy may be left without an adequate supply of rural workers. Rural job seekers will find themselves in demand in many nonfarm sectors. The result will be that the best and the brightest will leave for employment in urban areas. Labor-intensive farm states like California, Florida, and Michigan may find themselves short of seasonal and temporary workers unless,

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of course, new immigrants are brought into the United States. At this time, I do not believe that enough attention is being paid to this plausible phenomenon.

The continuation of off-farm migration of workers suggests that the farm sector will be increasingly affected by labor shortages of possibly serious magnitudes. How do we remedy this situation? Will society pay to generate seasonal pools of workers? Should we offer more year-round employment to existing farm labor and rural workers to keep them in the rural economy? Should we continue our immigration policies? These are issues we cannot ignore. Yet, few people are researching them today. Related to these questions, however, Christy and Figueroa ask us to be more knowledgeable of the Immigration Reform and Control Act of 1986 and other immigration policies. The issues they raise are very important for both rural employers and workers of the future.

Christy and Figueroa give considerable attention to the way we study change and the role of human capital. They advocate a "theory of change" which, according to them, is an institutional theory that looks at the interrelationships between technology, institutions, humans, and resources. I encourage such a perspective. Most contemporary problems of rural America are more social and institutional than technical in nature. The fact is, the economic well-being of most rural citizens does not depend on the prosperity of the farm sector. The future challenges are not merely ones of farm production but new challenges facing entire rural communities and people. In arguing for a "theory of change" Christy and Figueroa rightly note that "a change in technology requires individual and institutional change. Likewise, change in institutions influences the behavior of humans and informs organizational performance." However, I would criticize Christy and Figueroa in one minor way. The "theory of change" they propose is more a paradigm than a theory. It is an outline of the key components our research should address. But, if we are going to accept this design or paradigm or framework of research, then we must also ask how we are going to train and educate social scientists to work in this framework. How will we get our research institutions to contribute support to such research, more than likely interdisciplinary? Would we have to discard the neoclassical economic approach to study the changes they envision? I doubt it. But their plea to broaden the research focus is a good one.

Now I would like to comment on the paper by Allen and Thompson. They have gone beyond the usual review of literature by attempting to determine the causes of rural poverty. They have also focused their attention on the "rural" poor and have selected a very interesting set of independent variables to correlate with poverty. I am particularly pleased with their analysis of poverty according to race and ethnicity. It is evident that the poor in rural America differ by race. The number one problem of the white poor is poverty of female-headed households. Whereas the number one problem of the Black and Hispanic poor, according to the regressions, appears to be the relatively low number of household earners. Without this analysis I would have probably reversed the ranking of these factors for each racial group. I was also intrigued by the variable "industry structure." By dividing industries into two types, "secondary" and "primary," we have a typology which suggests that the rural poor are overrepresented in the "secondary sector," composed of (*a*) nondurable manufacturing; (*b*) retail trade; (*c*) business and repair services; (*d*) personal services; (*e*) entertainment and recreation services; (*f*) mining; and (*g*) agriculture, forestry, and fisheries. It is interesting to note however, that three of the industries included in this group (nos. *c*, *d*, and *e*) are going to grow, according to the projection of the Department of Labor. Allen and Thompson recommend greater job creation in the primary sector as a way to address rural poverty. I do not believe that form of job creation will absorb enough low-income wage workers. Instead of depending on more jobs in the primary sector, the policies also should be to change the conditions in the secondary sector—raise minimum wage, provide fringe benefits and child care, stablilize employment, and develop more opportunities for women and minorities to be the leaders in these industries.

The absence of absolute numbers regarding the magnitude of rural poverty concerns me. While Allen and Thompson refer to the rates and percentages of rural poor, they do not tell us how many are poor. I would like to fill in this gap by data I produced with my colleagues Ed Dolber-Smith and Douglas Gwynn from the 1988 CPS tapes. Table 1 corroborates the high incidences of poverty faced by the black and Hispanic populations in nonmetropolitan areas in 1988. But also evident is the high absolute number of non-Hispanic white poor. Moreover, it is apparent that poverty in nonmetropolitan America is disproportionately high given that nonmetropolitan areas contain only 23% of the na-

Table 1. Total U.S. and Nonmetropolitan Poverty by Race and Ethnicity, 1988

	Total Poor in America	Nonmetropolitan Poor	Percent Nonmetro Poor of Total Poor
Total population	32,506,826	8,979,687	27.6
Poverty rate (%)	13.5	17.0	
Non-Hispanic white	16,161,515	5,895,702	36.5
Poverty rate (%)	8.7	13.1	
Black population	9,668,033	2,259,783	23.4
Poverty rate (%)	33.0	44.0	
Hispanic population	5,461,371	510,725	9.4
Poverty rate (%)	28.1	36.3	

Source: Public Use File: Current Population Survey, March 1988. Hispanics can be of any race and are distinguished by ethnicity.

tion's people and 27.6% of the poor.

Allen and Thompson must rely on data for nonmetropolitan areas to serve as a proxy for rural areas because the annual CPS Public Use Files have no data on "rural" people. They do not point out, however, that a serious problem in rural social science research is the lack of a clear and precise definition for the "rural sector" and its people. Rural definitions for U.S. populations and places have been generally treated as residuals, as any population living in an area not designated as urban. This approach is rooted in criteria used by the U.S. Census Bureau. Referring to the Bureau's *1980 Census Users' Guide*, we find, for example, that "the urban population comprises all persons living in urbanized areas (UA's) and in places of 2,500 or more inhabitants outside UA's. The rural population consists of everyone else."

An interesting problem about this criterion is that a rural classification need not imply farm residence or a sparsely settled area because a small city or town is rural as long as it is outside a UA and has fewer than 2,500 inhabitants. Moreover, this "residual" criterion also leaves the problem that a "rural" area and population can exist within a Metropolitan Statistical Area (MSA). Again, according to the Census Bureau, an MSA is "a geographic area consisting of a large population nucleus—a census defined urbanized area—together with adjacent communities that have a high degree of economic and social integration with that nucleus."

With this definition for the MSA, we have the possibility that many MSAs contain "rural" people. As such, nonmetro data cannot and should not be used synonymously for rural data. One may ask if this causes a serious problem. Is not the nonmetropolitan concept a significant and meaningful synonym for rural? Does it make a difference in our research to ignore the rural population of MSAs?

My reserach with Kawamura, Gwynn, and Dolber-Smith found a large numerical difference in the count of rural poor when the rural people within MSAs were considered. We conducted a comparative analysis of the California poor, using 1980 census data, of both urban and rural populations within both MSAs and non-MSAs. It turns out that a large number of California's poorest rural people are subsumed in the metropolitan areas of Sacramento, Fresno, and Bakersfield. These rural, metropolitan poor are also different in some respects from the nonmetropolitan poor. They are largely Hispanic and white, with employment in agriculture and agribusiness. The nonmetropolitan poor in California are white and Native American (Kawamura et al).

I commend both presentations for addressing key demographic and social issues of rural America. I urge rural social scientists to continue research along the lines recommended by the authors.

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Human Capital, Economic Development, and the Rural Poor: Discussion

Claudia Parliament

Poverty is perceived by many as primarily an urban problem. Inner city poverty is concentrated and visible, but as long as the United States has gathered poverty statistics, a disproportionate share of the poor have been found to live in rural areas. If characteristics or causes of poverty are unique to rural areas, then policies can be designed to alleviate rural poverty. Unfortunately, the analyses provided in the two invited papers do not address the unique aspects of the rural poor. Neither paper justifies the need or proscribes policies to specifically target rural poverty.

Allen and Thompson begin with a review of the many deficiencies of the current measure of poverty. Their criticisms do not point out, however, that the current measure of poverty does not discriminate between poverty related to age or disability and poverty caused by lack of employment opportunity or adequate education. Allen and Thompson would strengthen their analysis of poverty among rural minorities if they focused on factors affecting the nonelderly and nondisabled persistently poor.

The disproportionate share of poverty among African Americans and Hispanics in nonmetro counties of the United States is well documented by Allen and Thompson. To underscore a need for policies directed to rural minorities, however, the unique differences between rural and urban poverty must be reviewed. The authors err by omitting a reference to the high incidence of poverty among Native Americans. A discussion of rural poverty among racial and ethnic minorities must at least acknowledge the incidence of poverty among the minority with one of the highest rates of rural residence and poverty.

With respect to the analysis of the determinants of poverty, Allen and Thompson should reconsider the use and interpretation of two of their explanatory variables. The industrial variable is more likely a proxy for wage differences due to skill levels than a measure of the size and dominance of firms, and the assumed monotonic effect of age on poverty disregards the higher incidence of poverty during child-bearing years and old age.

The lack of significance of southern residence on poverty may reflect the deterioration of jobs associated with agriculture, mining, and forestry in areas outside the South during the 1980s. The decline in natural resource-based industries during the decade significantly increased the incidence of poverty in resource-based rural counties in the West and Midwest. These relatively recent pockets of poverty have been referred to as the new rural poor (Stinson).

In the discussion of the policy implications of their results, Allen and Thompson first call for increasing Aid to Families with Dependent Children benefits, assisting females to enter the labor force, and providing adequate day care. These changes are needed for all single parent households living in poverty. The authors could strengthen the case of the rural poor if they underscored the difficulties of providing employment and day care in areas with sparse populations and vast distances between trade centers.

Allen and Thompson's discussion of the need to subsidize education should emphasize that, on average, rural schools have fewer resources, less adequate facilities, and less experienced teachers than urban areas (Ross and Rosenfeld). Many rural poor reside in school districts with the most limited resources.

The authors indicate that the existing civil rights and equal employment laws must be enforced to overcome the racism associated with poverty. They did not emphasize, however, that many small, rural firms may not be covered by federal equal employment laws.

In the second paper, Christy and Figueroa intend to show the detrimental effect of structural and institutional changes on ethnic minorities in

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rural America. They discuss the decline of nonwhite farming and the recent change in immigration policy with the passage of the 1986 Immigration Reform and Control Act (IRCA). Although the case studies are in themselves interesting, the theoretical connections between structural change and public policy, and the human capital needs of rural ethnic minorities are not made.

The authors imply that the African American exodus out of farming increased poverty, but no evidence is provided. Christy and Figueroa attribute the decline in landownership by nonwhites to credit policies, education, and intergenerational land transfers. The authors could have directly addressed the role of U.S. farm policy in the decline of nonwhite farmers. Farm policy promotes efficiency rather than equity, and the bias toward large, commercial farms promoted the massive dislocation of small minority farmers. The decline of nonwhite farmers is one of the unmeasured social costs of our farm policy. They also could have cited evidence that the Cooperative Extension Service devoted many of its resources to assisting large farms rather than small, minority farmers in the South (Baldwen), in support of their discrimination claims.

The effect of the change in immigration on Hispanics is the second change analyzed in the paper. To address the effects on rural ethnic minorities, however, the authors need to indicate the specific effects of IRCA on rural residents and migrant farm workers. They only note that IRCA may have the ambiguous effects of increasing both wages and discrimination among Hispanics.

The authors state that rural poverty must not be equated with farm poverty, and that rural poverty will not be solved by manipulating existing farm policy. This rationale may be appropriate given that only 8.5% of rural poor were farm residents in 1986 (Woods, Ross and Fisher). However, among rural households the highest incidence of poverty exists among small farmers and migrant farm workers, and thus farm policy may be the most appropriate vehicle to address their poverty.

The authors could expand their discussion of the need for human capital among rural minorities with an analysis of the structural decline of rural manufacturing. Rural areas successfully attracted new manufacturing jobs during the 1960s and 1970s, partially the result of lower labor costs. This growth of manufacturing made possible the rise from poverty of many rural households, particularly in the rural South where most of the manufacturing-dependent counties are now located. Since 1979, however, manufacturing employment has declined, and rural manufacturing industries may not be able to adapt to technological change and competition because of the relatively unskilled rural labor force. The authors' call for increased human capital investments in rural ethnic minorities continues to be a crucial rural development tool.

Both papers indicate the need to move toward a broader definition of poverty in recognition that disadvantage is a multifaceted phenomenon that is not adequately described solely by income. A better indicator of poverty may include measures of illiteracy, crime, substance abuse, and labor force attachment. These characteristics have been used to describe the "underclass"—those socially isolated and in persistent poverty (Wilson, Ruggles and Marton). Although the development of policies directed at the underclass are currently dominated by urban analysts, the characteristics also apply to the persistently poor in rural areas, and rural analysts should participate in the development of future poverty policies.

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Transactions Costs and Efficiency in Western Water Allocation

Bonnie G. Colby

Controversy over the appropriate balance between market and regulatory approaches to allocation makes resource economics a fascinating and dynamic area of inquiry. Over the last twenty years, the tension between market forces and broader social values has become increasingly evident in state water transfer policies. Through the 1950s, water transfers out of agriculture were uncommon and were discouraged by some western states. However, the American West's economic transition from ranching, irrigated farming, and mining to urban growth, services, tourism, and industry brings strong incentives to transfer some water out of agriculture.

Economists argue that market forces should play a greater role in water allocation—emphasizing the inefficiency of allocating water to grow low value and surplus crops, while nonagricultural water users struggle to develop expensive new supplies. Agriculture accounts for 85%–95% of water use in many western states, and the cost of reducing irrigated acreage so that water can be available for other uses is generally far less than the cost of developing new water supplies (Young). Moreover, transfer of only a small portion of water used in agriculture would be sufficient to satisfy foreseeable nonagricultural water demands, so disruption of western U.S. agricultural production would be negligible (Tregarthen, Young).

Over the last decade, market transfers have become a more common means to reallocate water, though nowhere could such voluntary transactions be characterized as a "free market" (Saliba and Bush). Every western state imposes conditions on water transfers. Such policies generate uncertainties and costs for transferors and have been described as inefficient and unnecessary impositions on the market (Tregarthen, Anderson and Johnson). Should public policy seek to minimize the cost of transferring water, or can transactions costs actually facilitate efficient reallocation by accounting for social costs of transfers?

Transactions costs are generally characterized as factors that prevent markets from operating efficiently or as factors that prevent markets from forming altogether (Coase, Demsetz, Cheung, Tregarthen, Crouter). In western U.S. water markets, transactions costs are incurred in searching for trading partners, ascertaining the characteristics of water commodities, negotiating price and other terms of transfer, and obtaining legal approval for the proposed change in water use (Colby et al.). This paper addresses the latter category of transactions costs, termed policy-induced transactions costs (PITC) in this discussion. Transferors incur PITC as they seek to obtain state approval to transfer a water right to a new place and purpose of use. PITC may include attorneys' fees, engineering and hydrologic studies, court costs, and fees paid to state agencies. PITC specifically exclude the price paid for the water right and the costs of implementing a transfer once it has been approved because these costs are not specifically attributable to state policies.

This paper evaluates PITC generated by state water transfer policies and argues that PITC force consideration of externalities that would otherwise be ignored by water buyers and sellers negotiating in their own best interests, concluding that PITC have a legitimate role in promoting efficient water allocation. Data from several western states with active water markets are used to analyze the economic incentives and distributional impacts of transactions costs imposed by state water transfer policies.

The Institutional Framework—Water Transfers and State Policies

Western cities pioneered the era of western water reallocation by purchasing irrigated land, some-

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times entire irrigation districts, to acquire water rights for urban development (Saliba and Bush). While city growth is still the driving force behind water markets, in the late 1980s new forces for reallocation emerged. Water transfers to support wildlife, fisheries, and recreation have become more common as the role of water in supporting environmental amenities and tourism is increasingly recognized (Colby 1990). Cities and environmental interests, alarmed by the droughts of the 1980s, now selectively seek water supplies that will be reliable even during dry years and so place a premium on rights with the highest priorities. Since irrigators' rights are typically senior and are most likely to be reliable during drought, they are a valuable commodity in many areas. While water transfers routinely occur among neighboring farmers in many areas of the West, this article focuses upon transfers from agricultural to nonagricultural water use. These transfers, which often involve moving water from one basin to another and from rural to urban areas, generate considerable controversy and demand for changes in public policies governing water transfers.

Market exchanges promote flexibility, allowing water allocations to adapt to changing economic conditions and new social values. Water transfers can also generate externalities. While transfers can create positive externalities in the area to which water is being moved, this paper focuses on negative impacts because these lie at the heart of controversies over water transfer policy. Negative externalities include reduced water supplies for other water right holders, diminished economic activity in communities from which water is taken, lower river flows, and degradation of water quality, fish and wildlife habitat, and recreation opportunities (Saliba and Bush, Kapaloski). Local direct and secondary economic losses from reduced irrigated acreage are typically small relative to the benefits created by new uses of the water (Howe, Lazo, and Weber, this issue; Young). The most significant externalities are probably those associated with recreational and environmental water values and with water quality. Benefits generated by water instream are often classic public goods not conducive to well-defined property rights and characterized by nonrivalry, nonexcludability and misallocation in private market exchanges. A number of studies indicate that leaving water instream can create economic benefits that exceed the benefits from transfers and diversions for offstream uses (Daubert and Young, Loomis, Ward). Moreover, streamflows and wetlands will become more highly valued as growing urban populations demand opportunities to recreate on free-flowing waters and view wildlife, and as water providers and waste water dischargers rely on the assimilative capacity of rivers and marshes to meet more stringent water quality standards. These public good aspects of water allocation are generally neglected when private water transfer agreements are negotiated.

Policy makers are struggling to balance these externalities with the economic benefits and flexibility that transfers can provide. Western states require prior evaluation of transfer proposals before approval is granted for changes in the purpose and place of use of a water right (Colby, McGinnis, and Rait). However, different types of third-party impacts are accorded markedly different degrees of importance in western water law. Foremost among the externalities considered is reduced water supplies for other water right holders. Other impacts are addressed in only a few states.

Those seeking to transfer a water right to a new use must file an application with the state water agency. Applicants often hire attorneys and engineers to help prepare the application. The scarcity of water supplies relative to demand and the degree of controversy surrounding water transfers affects applicants' need to hire experts. For example, there are no remaining unclaimed water supplies in eastern Colorado, Colorado transfers require judicial proceedings, transfers are typically heavily contested, and consultants are typically retained at an early stage. In contrast, the transfer approval process in Idaho and Wyoming is much less formal, partly because there has been less pressure for water transfers in these states. In areas where there is less competition for existing water sources, procedures are simpler, water transfers generate less conflict, and PITC are lower.

Filing a protest is the primary means for parties who object to the proposed transfer to influence the state agency review process, though not everyone who believes they may be adversely affected can legally file a protest. The earliest, and still the most common, legal basis for protesting a transfer is impairment of existing water rights. Western state laws historically emphasized protection of existing water rights so that water users would have secure incentives to make the investments necessary to develop the West. However, water right holders do not represent the multiple interests that benefit from water resources and that experience losses as a result of water transfers. Most states limit ac-

cess to water rights for instream uses. Only two of the thirteen western states allow private parties to acquire water rights for maintaining streamflows (MacDonnell 1989).

Recreationists, farm equipment dealers, streamside homeowners, rafting outfitters, and bait shops all have an economic interest in maintaining streamflows but generally cannot obtain water rights to protect their interests. Further, water quality is poorly integrated into most states' water laws. Waste treatment facilities are designed based on historic streamflow levels and rely on the dilution provided by flows to assure compliance with discharge standards. However, in most western states water rights cannot be acquired for protecting water quality, and impairment of water quality is not a valid basis for protesting a water transfer (Kapaloski). State policies which limit who may hold water rights, which disallow protests by those who do not hold water rights, and which limit the reasons for which a protest may be filed, constrain the externalities which are considered when a transfer proposal is evaluated.

When legally valid protests are filed, transfer approval is significantly delayed as the applicant and protestants argue over the magnitude of transfer impacts and the extent of mitigation or compensation. If the parties can agree, their negotiated modifications of the transfer proposal are submitted to the state agency and transfer approval normally follows. If the applicant and protestants cannot come to an agreement, the state agency will hold hearings and make a ruling on the transfer application. The ruling may approve the transfer as requested by the applicant, grant conditional approval with modifications to satisfy protestants' concerns, or deny the transfer altogether. Parties dissatisfied with the state's decision may appeal to state courts. The threat of a costly, protracted hearing followed by an unpredictable ruling on the transfer application is a powerful incentive for the parties to negotiate a settlement.

Transactions Costs and Efficient Water Transfers

The ability to impose transactions costs on those proposing to transfer water, an ability conferred by state laws governing who may hold water rights and file protests, represents bargaining power in the water allocation process. Market transactions are undertaken for economic gain, based on the perception that water supplies will generate higher returns in their new use than in their former use. The power to erode this expected gain through imposing transactions costs gives third parties leverage with transfer proponents and a role in water reallocation decisions.

"Optimal" Transactions Costs

For PITC to facilitate efficient water allocation, they would have to provide incentives such that water reallocation occurs if and only if the social benefits of transferring water exceed the social costs. Social welfare is maximized when water transfers occur to the point where the marginal social benefits of transferring one more acre-foot equal the marginal social costs. Given the public good nature of many water uses and pervasive externalities associated with water transfer, private marginal costs of water transfers are likely to diverge from the social marginal costs. Transactions costs could promote efficient allocation if they behave as a Pigouvian tax, causing private decision makers to account for social costs by "taxing" transferors through PITC.

Figure 1a illustrates how PITC could, in theory, enhance efficiency. WTP_1 represents the original market demand for water in urban use, and WTP_2 represents a new higher level of demand, prompted by urban growth. *PMC*, private marginal costs, is the supply curve for cities seeking to transfer water out of agriculture and is based on irrigators' willingness to sell water. *PMC* measures farmers' foregone net benefits when water is removed from agricultural use. At the original equilibrium allocation, Q_1 units of water are used by cities, and the remainder of regional supplies are in agricultural use. The new market allocation would be at Q_2, and $Q_2 - Q_1$ units of water would be transferred from agriculture to the new urban use. Suppose, however, that the social marginal costs of water transfers exceed *PMC* by an amount represented graphically by the wedge between *SMC* and *PMC*. This divergence between *PMC* and *SMC* reflects those negative impacts of transferring water out of agriculture that are not already incorporated into *PMC*, the sellers' own foregone net benefits. The socially optimal transfer is $Q^* - Q_1$, a smaller amount of water than would be transferred if only private costs and benefits were considered. If PITC reduce the transferors' net willingness to pay to WTP_3 (where WTP_3 is WTP_2 minus *PITC*), then the privately negotiated quantity transferred will approximate the opti-

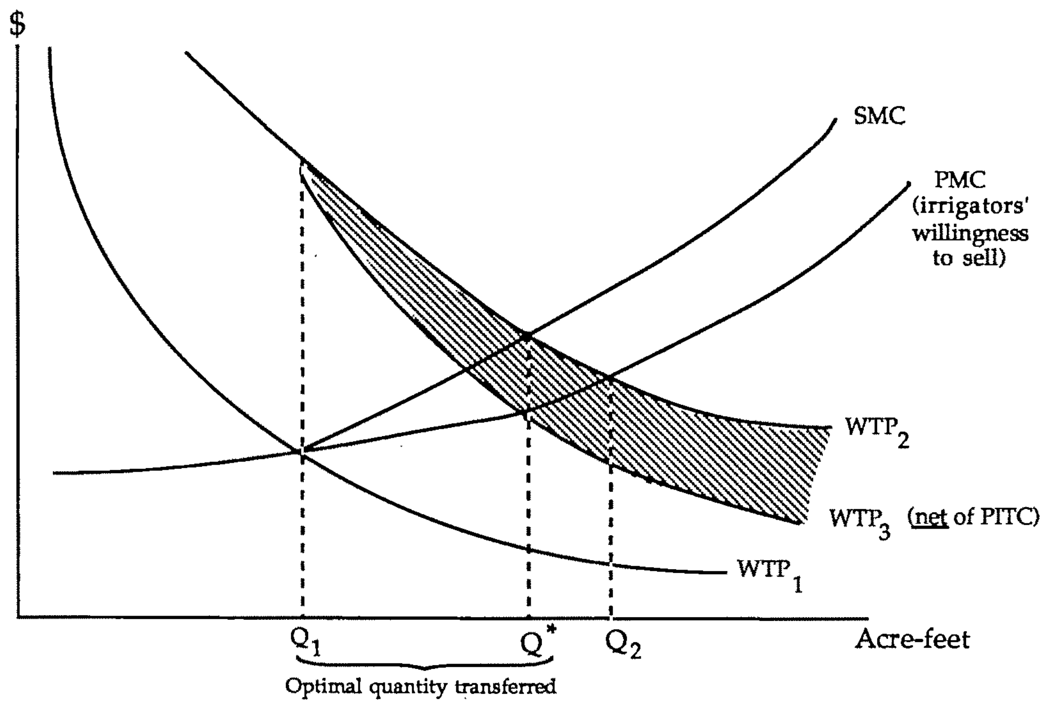

Figure 1a. Optimal PITC

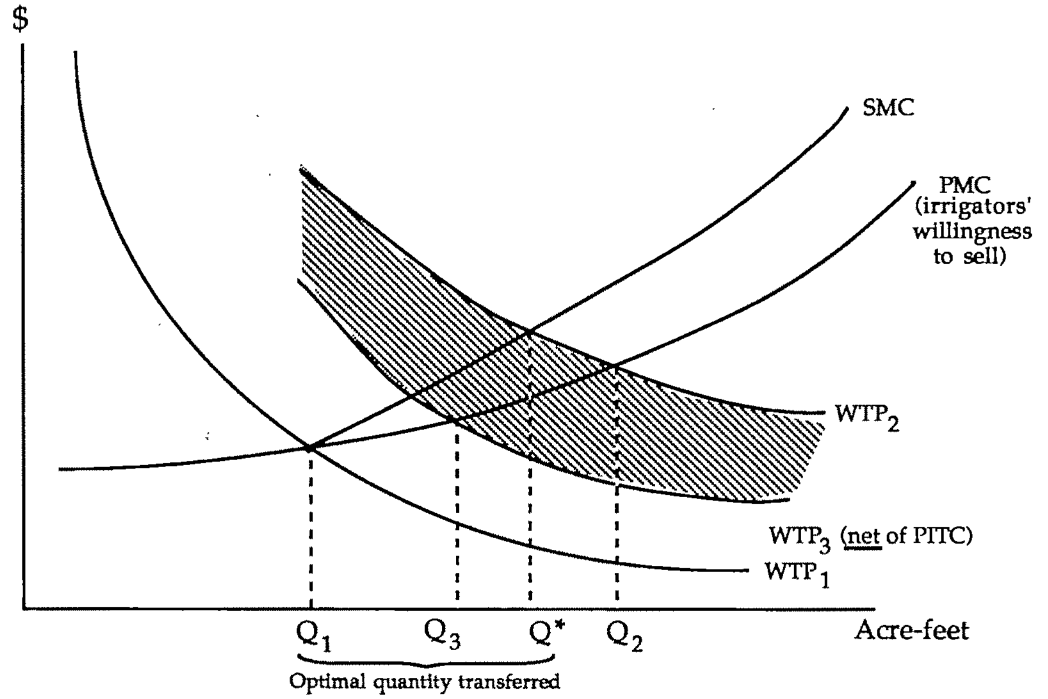

Figure 1b. Overregulation; PITC are too high

mal transfer quantity, $Q^* - Q_1$. "Optimal" PITC, represented by the vertical height of the shaded area between WTP_2 and WTP_3, equal the difference between *PMC* and *SMC* for each quantity of water transferred and cause transferors to account for social costs when making a market transaction.

In principle, PITC that reduce willingness to pay for water transfers could promote economic efficiency. The shaded area in figure 1a is not a net loss to society but is rather an income redistribution (like a Pigouvian tax) from transfer applicants to those who provide services in the transfer approval process. Transactions costs are not "money down a rathole," they are expended to clarify, protect and transfer property rights (Randall). Rights to use water are extremely heterogenous, sometimes poorly defined, and involve pervasive interdependencies. It is not costless to identify the nature and magnitude of third party impacts related to water transfers and PITC are part of the "price" of developing transferable private property rights in a resource which has extensive public good attributes.

"Overregulation" of transfers, such that private and social gains from transfers are eroded by high PITC, is also possible. This is shown in figure 1b. In the absence of any PITC, a larger than optimal amount of water ($Q_2 - Q_1$) would be transferred. With high PITC, indicated as the shaded area, WTP_3 represents urban willingness-to-pay for water transferred net of PITC. For any quantity of water transferred, PITC exceeds the difference between social and private marginal costs. Costs of complying with state regulations are so high that a less-than-optimal quantity, $Q_3 - Q_1$, is transferred to urban use and social net benefits are reduced compared to the optimal transfer, $Q^* - Q_1$. Given that either "overregulation" (PITC too high) or "underregulation" (PITC too low) is possible, in theory, what do we know about actual PITC in the western states?

PITC in Western States Water Transfers

Several recent studies examine the cost of obtaining state approval to transfer water rights from agriculture to other uses in selected western states. The data do not permit rigorous testing of an overregulation or underregulation hypothesis but they provide some indications on the magnitude and distribution of PITC. Colby et al. analyzed applicant, protestant, and state agency costs for water transfers in several states with active water markets. Data on applicants' and protestants' PITC were collected for transfers initiated in the 1980s. This study sampled professionals involved in water transfers who expressed a willingness to participate in the study. While this permitted the collection of detailed information on PITC, the results are not based on a random sample of all transfers and, therefore, are not necessarily representative. However, the results are similar to those produced by another study (MacDonnell 1990) that analyzed characteristics of all transfer applications filed in Colorado, New Mexico, and Utah over a ten-year period.

Colby et al. found that applicants' PITC averaged \$91 per acre-foot of water transferred with considerable variation among states. Applicants' PITC in Colorado averaged \$187 per acre-foot, \$54 in New Mexico, and \$66 in Utah. Another measure of PITC involves the opportunity costs to transfer applicants of time delays while waiting for state agency approval of a transfer proposal. This period is measured in months from the time a transfer application is filed to the date of the state agency decision. Time delays varied considerably by state; 29 months in Colorado, 4.3 in New Mexico, and 5 in Utah.

Applicant costs per acre-foot transferred vary with the market value of water in the areas studied by Colby et al. Applicant costs were higher on a unit basis in the front range of Colorado, where water rights often sell for \$4,000 or more per acre-foot, and were significantly lower in the middle Rio Grande Valley of New Mexico, where water rights sell for under \$1,000 per acre-foot. This study found that applicant costs per acre-foot averaged 6% of the price paid by the applicant for water rights to transfer.

Statistical analysis of the Colby et al. data revealed that larger transfers have lower PITC per acre-foot transferred, indicating some economies of scale. Protests have a significant and positive impact on applicant cost per acre-foot. Time delay, a measure of applicants' opportunity costs, is also significantly and positively related to whether or not protests were filed. In Colorado, transfers involving water rights in the most "water scarce" areas of the state had significantly higher applicant unit costs and time delays than elsewhere. These results suggest that PITC are higher where the economic values that may be affected by the proposed transfer are higher—in areas where water is more scarce and water rights sell for a higher price.

Colby et al. also collected data on costs incurred by those protesting transfer applications in Colorado. The number of protests filed per

transfer application ranged from zero to 15. Those filing protests spent between $750 and $24,400 apiece, with an average cost per protest filed of $7,052, indicating that parties protesting a transfer to protect their own water rights can incur significant costs.

MacDonnell (1990) compared characteristics of water transfers in several western states and found variation among states similar to Colby et al. In Colorado, 80% of transfer applications were eventually approved over the ten-year study period (1975–84), while 90% were approved in Utah and 95% in New Mexico. (Approval does not imply that the applicant obtained permission to transfer as much water as originally requested because many approvals are conditioned on modifying the original transfer proposal to satisfy objectors.) MacDonnell found that 60% of all transfers were protested in Colorado over the period 1975 to 1984, and that it took an average of 21 months to obtain state approval. In sharp contrast, only 5% of transfer applications were protested in New Mexico over this same period, and the average time to obtain approval was 5.8 months. In Utah, about 15% of change applications were protested and the average time to obtain approval was 9 months.

One explanation for the variation among states in time delays, approval rates, and frequency of protests lies in the different types of transfers occurring in each state. Transfers out of agriculture are generally more controversial than transfers among farmers. Transfers out of agriculture account for 80% of transfers in Colorado and only 30%–40% of the transfers that have occurred in New Mexico and Utah over the last ten years (MacDonnell 1990).

The MacDonnell data indicate interesting variations in transactions costs and time delays within individual states. In Colorado, 84% of transfer proposals in the most populous and "water scarce" basin in Colorado were protested, compared to only 40% in the least competitive basins in the state. In New Mexico, larger transfers took much longer to win state approval—the average volume of New Mexico transfers approved in less than three months was 79 AF compared to an average volume of 312 AF for transfers taking more than four years to approve. In Utah, one basin accounts for a disproportionately large number of all protests filed in the state. In this basin, which is experiencing high growth rates and has no remaining unclaimed water supplies, approval time delays are twice as long as typical elsewhere in Utah. These intrastate comparisons indicate that PITC are higher in areas where water is more scarce and more valuable, transfers are more controversial, and the externalities of water transfers are more likely to be significant.

Policy Implications

Consider the following hypothesis: The transactions costs generated by state regulation of water transfers out of agriculture are lower than would be socially optimal. This runs counter to the view that government regulation of water transfers is excessive and prevents markets from efficiently allocating western water. While the overregulation view may apply to impediments to transferring water out of federally subsidized irrigation projects (barriers which do not originate in state water law), state policies make transfers less expensive than they should be, by failing to account for externalities associated with transfers. This argument rests on the following points:

(*a*) State laws specifically exclude some parties who may experience significant externalities from filing protests and from influencing the conditions of transfer approval. In general, only neighboring water right holders can force their concerns to be accounted for. Wastewater treatment managers, recreationists, environmental interests, and persons who live along streams or make their living in recreation or agriculturally linked economic sectors typically have no role in the evaluation process. Current levels of transactions costs reflect only one of the many types of externalities that are associated with water transfers and neglect the public good aspects of water resources.

(*b*) Current PITC related to impacts on other water right holders do not appear to be excessive, given water values in the areas studied. Those who do have legal basis to protest a transfer, other water right holders, act in their own self-interest to protect the benefits they receive from their water right. It can be costly to file a protest, and one must assume protestants consider their expected net payoff before entering the fray. Payoffs to protestants take the form of modifications in the transfer proposal to eliminate impairment of protestants' water supplies and sometimes monetary compensation for accepting impairments. The costs of protesting serve to inhibit (though probably not eliminate) frivolous protests filed purely to obtain payoffs from transfer applicants. The costs incurred by applicants and protestants appear to reflect the

economic values at stake. PITC are significantly higher in areas where existing water supplies are fully appropriated, importation or development of new supplies is expensive, and demand for water is increasing. In these areas, the value of water is high, and high PITC seem appropriate, not an indication of inefficiency and overregulation.

While the hypothesis that PITC are lower than optimal cannot be empirically proven, there is also no convincing evidence for presuming, as much of the literature on water allocation does, that western states overregulate water transfers and that public policy should make transfers cheaper and faster. Water transfers occur regularly in the three states for which PITC data was collected, with an average of 70, 100, and 350 water transfers approved each year over the period 1975–84 in Colorado, New Mexico and Utah, respectively. With PITC averaging only a small fraction (6%) of the prices paid for water rights, current state policies do not appear to overly burden market reallocation (Colby et al).

It would be farfetched to argue that the optimal PITC illustrated in figure 1a portray the actual situation and that current PITC accurately represent the social costs of transfers. Market imperfections have been amply documented for western water transfers (Anderson and Johnson, Saliba and Bush). Further, given the lack of consideration for any externalities other than those experienced by water right holders, PITC probably underrepresent social costs. However, the preliminary data available indicate that PITC are "well-behaved," not inconsistent with the incentives that would be created by a Pigouvian tax on water transfers. The higher the value of water, the greater the economic impacts on other water right holders and the higher the "tax" on transfers in the form of PITC.

Why not tax water transfers directly to account for external impacts? Determining the optimal rate for such a tax would require complete centralized information on all parties' marginal costs and benefits. Existing information regarding externalities is dispersed among affected parties, hydrologic and economic studies to identify the magnitude and distribution of impacts are costly and few would argue that state agencies should be assigned the task of collecting the information needed to impose a credible Pigouvian tax. The current institutional framework relies on autonomous, self-interested transfer applicants and protestants to incur costs to the point where it is no longer worthwhile to do so. The benefits and external impacts of transfers are considered as each party determines the expenses they will incur to pursue or oppose a particular water transfer and the "deals" they are willing to make to reach a settlement. However, to the extent that state laws exclude those who have real economic interests from participating in the process, some social costs are being ignored.

Improvements in the Current Institutional Framework

Having argued that PITC have a legitimate role in the water reallocation process, given public goods and externalities associated with transfers, there are indications that some state policies exaggerate PITC beyond the social costs they should reflect. Colorado has much higher PITC and longer time delays for approval than other western states. Part of these differences result from higher water values in Colorado, as evidenced by significantly higher market prices than are typical in other states (Saliba and Bush). However, Colorado PITC are out of proportion with water prices, compared to other states. Colby et al. found that, while PITC average 6% of water rights prices for all states studied, they average 12% for Colorado. One might hypothesize that PITC are higher in Colorado because a broader range of values are protected when transfer proposals are evaluated in that state, but Colorado water law actually lags behind other states in considering instream and public interest values (Colby 1988).

In Colorado, changes in water use are evaluated in the state water court system in formal judicial proceedings. Fully one-third of all U.S. attorneys specializing in water law are members of the Colorado Bar, and attorneys fees account for the bulk of PITC, leading one to suspect rent-seeking behavior. There are probably rents created by barriers to entry in the Colorado legal profession (state bar exams) and there are rents to be captured as water is reallocated from lower-valued to higher-valued uses. The Colorado water bar seems to be a primary beneficiary of the state's court-based approach to governing water transfers, as over half of PITC go to the attorneys representing applicants and protestants. A smaller proportion go for engineering and hydrologic studies to measure impacts and for compensation to injured third parties. While current PITC do reflect externalities imposed on water right holders and play a role in promoting efficiency, they also redistribute the rents from

water transfers in a manner that raises equity concerns. Where taxation and redistribution of profits from water transfers have been contemplated, the intended beneficiaries have been rural counties, wildlife preserves and state stream protection programs, not lawyers (Colby 1990).

One goal of policy changes should be to generate information on the externalities that accompany water transfers in a least-cost manner. Most disputes between applicants and protestants involve the quantity of water that should be transferable. States should establish a transferable quantity per irrigated acre. New Mexico, with the lowest PITC of the states studied, sets a standard quantity of water that may be transferred per unit of irrigated land retired. Parties who disagree with this quantity bear the costs of proving some other amount is appropriate. In contrast, the Colorado system invites all parties to provide evidence on transferable quantity, with considerably higher PITC incurred for engineering and legal studies. As a second recommendation, judicial proceedings should not be the first forum for evaluating a transfer proposal as in Colorado. The adversarial nature of court proceedings prompts "overinvestment" in attorneys and other experts. Third, data developed for previous transfers (river basin and groundwater models, engineering reports, crop consumptive use studies, etc.) should be publicly available and used to build up a cumulative information base for evaluating transfer impacts, with the goal of reducing information costs.

A second goal of policy should be to broaden the types of externalities that are considered. Water rights should be accessible for instream uses, through transferring an existing right or appropriating unclaimed water, just as they are for offstream uses. The ability to acquire water rights for maintaining streamflows would allow water quality managers, recreationists, and environmental interests to become right holders and give them a legal basis for protesting proposed transfers. Some states' laws allow "public interest" factors to be considered when a transfer proposal is evaluated, but public interest provisions are rarely used to contest a proposed transfer because the concept is new and ill-defined and few specific criteria exist. States need to define the public goods attributes of water that they wish to protect and to incorporate these into their transfer policies. Some are already doing so (Colby, McGinnis, and Rait). These changes will undoubtedly raise PITC, but will also permit a broader range of social costs to be accounted for as water is reallocated.

Summary

Western states' water laws evolved to protect those who diverted water for offstream uses such as mining and agriculture, granting property rights in water for these early uses. Historically, the primary concern in evaluating proposed water transfers has been protection of water right holders. Western state economies have changed and so have the values that the West's water institutions must serve. Broader access to property rights in water and to the transfer approval process can allow a wider array of externalities to be considered and will make water transfers more expensive than previously. Given that important values can be affected by transfers, is there a sound economic rationale for making water transfers as inexpensive as possible? High PITC reflect the substantial and multiple economic benefits associated with water in various uses, benefits which can be impaired by a transfer. PITC are high in areas where new water supplies are locally unavailable and expensive to import, demand for water is increasing and water rights are valuable property. PITC are lower in states and in river basins where unclaimed water is still available, there is less pressure for transfers and water rights are lower in value. Transactions costs generated by state policies are a reasonable means to account for social costs of water transfers, given the immense centralized information requirements for an optimal tax on transfers. The present institutional structure gives affected parties, each weighing their own costs and benefits, an incentive to generate information on transfer impacts and to negotiate transfer conditions and mitigation of externalities. State water transfer criteria are not arbitrary hindrances imposed upon the marketplace. These policies protect existing investments by water right holders and, as they are broadened to include other interests, they can reflect public good values affected by water use and transfer.

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Socioeconomic Impacts of Water Farming on Rural Areas of Origin in Arizona

Alberta H. Charney and Gary C. Woodard

A land rush of sorts has occurred in parts of rural Arizona during the last six years. Municipalities, developers, speculators, and the federal government all have purchased or acquired leases to over one-half million acres of land, with half the acquisitions made by private parties, 30% by municipalities and 20% by the federal government (Woodard and McCarthy). Some of the land is irrigated agricultural land, some is rangeland, and some is raw desert. The purchasers have acquired the land not for the value of the land or its crops or any structures but for its associated water rights. This phenomenon, known as "water farming," has been occurring in other parts of the West for decades (Colby, this issue). Its emergence in Arizona was triggered by certain provisions of the state's 1980 Groundwater Management Act (Checchio, Woodard et al.).

Municipal areas located in designated Active Management Areas that plan to grow beyond the year 2001 must convince the Arizona Department of Water Resources that they have a 100 years assured water supply for new development. Historically, Arizona municipalities have relied on a mix of surface and groundwater to meet growing urban demand. However, there is little or no unappropriated surface water in the state, and the Safe Yield provision of the Groundwater Management Act severely limits future groundwater pumpage from aquifers underlying urban lands (Woodard and Checchio). As a result, municipal water providers plan to transfer water to urban areas, eliminating much of the irrigated agriculture in the areas of origin.

Arizona's water transfer "market" can be distinguished from that of Colorado, New Mexico, Utah, Nevada, and most other western states in the following ways:

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(*a*) Acquisitions are driven by legal requirements to secure "paper" water rights more than any perceived need for the water. If the quantity of water secured or being negotiated for transfer all was put to municipal and industrial uses at 140 gallons per capita per day (the targeted consumption rate of ADWR), then enough water for an additional 3.2 million persons is involved. Current state population is just under 3.7 million.

(*b*) The transactions are very few in number but very large in terms of acres, acre-feet, and dollars. The "typical" water farm in Arizona consists of 10,000 acres of deeded land plus 20,000 acres of leased land, has a price of $15 million, and can supply 15,000 acre-feet per year, based on a 100-year pumping regime for groundwater.

(*c*) The focus is on unquantified groundwater rights, not quantified surface water rights. Of eighteen water farms, ten are groundwater only, four involve both surface and groundwater, and four involve surface water only (three of which are federal acquisitions of Colorado River water to satisfy various claims). Of the roughly half-million acre-feet of potential annual supply, over three-quarters is groundwater.

Water Farm Characteristics

Certain characteristics distinguish a good potential water farm. Access to a large, high-quality source of surface or groundwater is one element. Being able to purchase large, contiguous tracts of land at reasonable prices also is important when acquiring access to unquantified groundwater rights. And a reliable, low-cost means of transporting the water from area of origin to area of use is essential, as the cost of infrastructure to transport the water can greatly exceed the cost of the water farm itself. West-central Arizona, with its high-quality groundwater aquifers underlying farms and ranches de-

preciated by the depressed agricultural economy and bisected by the Central Arizona Project aqueduct, has all these characteristics. The CAP aqueduct, which will bring Colorado River water to the Phoenix and Tucson metropolitan areas, offers such an attractive means of transporting other waters to the state's urban areas that nearly all water farming activity to date is concentrated in La Paz and western Maricopa Counties (Checchio, Woodard and McCarthy). Of the eighteen actual and proposed transactions, seven involve land lying wholly within La Paz County and four involve land partly within La Paz. As a result, the impacts of water farming also are concentrated. This has caused considerable concern in La Paz County, which is 95% public land and lacks a diverse economic base.

Economic theory suggests that the first water to move from agricultural uses will be from the least productive, or marginal, irrigated land. This pattern is observed in the purchase and retirement of the thirty-three cotton farms in the Avra Valley near Tucson over a sixteen-year period because those farms with the lowest per-acre yields sold out first and the more productive farms remained in operation another ten years. However, if location relative to existing aqueducts or seniority of rights is important to municipal purchasers (Howe, Lazo, and Weber, this issue), then more productive land with higher-valued crops may be purchased first. Also, when groundwater is involved, there is no "use it or lose it" incentive to continue cultivating the land until the water is transported so as to maintain the rights and produce incidental profits from the farming activity. In fact, because most groundwater pumped in Arizona is mined groundwater, there is an incentive to retire the land to preserve the water. For principally political reasons, a number of short-term lease-backs have been negotiated in Arizona. However, most irrigated agriculture on water farms likely will be retired in the near future.

Economic Impacts

Assessing the economic impact of water transfers on La Paz County involves estimating in economic measures the difference between what would occur with and without the water transfers. The following analysis determines the economic impact of retiring a hypothetical "typical" 1,000 acres of farmland in La Paz County. The results are then used to discuss tax revenue impacts for local governments.

Several different types of "impacts" typically are distinguished. "Direct" impacts are those employment and income impacts that are immediate and explicitly related to agriculture. In the case of assessing the employment impact of reduced agricultural acreage in La Paz County, the direct impacts include the change in employment at all establishments (farms, orchards, etc.) primarily engaged in the production of cotton, alfalfa, vegetables, fruits, nuts, and other crops.

Indirect impacts are determined by forward and backward inter-industry linkages, or the extent that agricultural products either are used in the production of other locally produced products (e.g., alfalfa cubes, ginned cotton) or that agricultural products utilize raw materials or intermediate products or services that also are provided locally. These technically linked sectors may be support activities, such as crop and soil services, farm management services, and legal services, as well as intermediate manufactured goods (e.g., seed and fertilizer).

Induced impacts occur through changes in local income flows and population changes. Proprietors and employees of the agricultural sector and of the technically linked sector earn income. This income and the consumption habits of these proprietors and employees determine the level of activity of the remaining (nonbasic) sectors. Person A, working on farms or in related industries, earns money which is spent buying goods and services. In doing so, she provides employment for person B in one of the local market-oriented sectors. In turn, B spends his income and provides employment for person C, also working in the local-oriented sectors, and so on.

Another induced impact occurs through changes in population. When employment falls, the change must be reflected in either an increase in the unemployment rate, a drop in the labor force participation rate as discouraged job seekers drop out of the labor market, or an outmigration of people seeking employment elsewhere. Typically, a reduction in employment results in all three of these changes occurring to one degree or another. If the decline in employment results in increased unemployment or discouraged workers, then the induced income impact described above accurately controls for these changes. However, when outmigration occurs, there are additional induced impacts because vacant housing results in declines in construction and construction-related employment.

A combination of methods is used to compute

the economic impacts resulting from constraints imposed by data limitations. The primary constraint was lack of time-series data on La Paz County, which split off from neighboring Yuma County in 1983. Consequently, employment and income data exist only since 1983, and traditional econometric approaches cannot be used. The present analysis utilizes a survey of growers to determine farm budgets, a survey of agriculture-related businesses to determine the nature of the services provided in La Paz County, and a telephone survey of a variety of other businesses in La Paz County. These surveys, combined with detailed employment data for La Paz County, permit all employment by sector that is directly or indirectly related to agriculture to be identified (Charney and Woodard).

Income- and population-induced impacts are determined using a large-scale econometric model of Arizona and its three major subcomponent areas: Maricopa County, Pima County, and the nonurban balance of state. This econometric model, while designed for impact analysis, lacks sufficient detail in the agricultural and related sectors to be useful in assessing the direct and indirect impacts. However, its structure easily is adapted to generate income- and population-induced effects (Charney and Taylor).

Table 1a presents direct plus indirect, induced, and total impacts of retiring 1,000 acres of agricultural land. For each 1,000 acres retired, La Paz employment falls by approximately seventeen employees. Of these seventeen employees, 10.5 are direct or indirect impacts and 6.5 are income or population induced. Of the 10.5 direct and indirect jobs, 65% are in farming and 16% are in agricultural services (see table 1b). There are additional indirect impacts in construction; manufacturing (e.g., production of animal feed and cottonseed oil); trade (particularly farm machinery and equipment and automobiles and parts); services; and small amounts in transportation, communications, public utilities; and finance, insurance, and real estate. The sectoral mix of the induced impacts is very different from the direct and indirect impacts, with income-induced impacts concentrated in the trade and service sectors, while the population-induced impacts primarily are in the construction and real estate sectors. The personal income impact of retiring 1,000 acres of farmland is approximately $363,000. Of this, $271,000 is the direct and indirect impact, and $92,000 results from induced effects. The direct and indirect income per employee impact (the income impact divided by the employment impact in table 1a) is large relative to the induced income per employee impact for two reasons. First, income per sector includes both labor and proprietors' income, which results in relatively high income per employee figures for the farm sector. Second, the induced impacts are concentrated in low-wage sectors, such as trade and services.

The estimated per acre impact of water transfers is larger than that of some other studies for several reasons. First, this analysis assesses the impact of retiring 1,000 acres of farmland. Other studies deal with the retirement of a combination of farmland, rangeland, and unimproved land. The land purchased for water transfers in Arizona also is a mix of farmland, rangeland, and raw desert; however, the impact analysis is based on 1,000 acres of the most productive, i.e., farmland. Second, less than half the farmland slated for water farms in La Paz County is in comparatively low-valued crops, such as alfalfa; the remainder is in higher-valued crops, such as cotton, grains, fruits, vegetables, and nuts. Third, the method used to generate these numbers, a method that combines input-output concepts with survey data and the simulation re-

Table 1a. Estimated Economic Impacts of Retiring 1,000 Acres of Agricultural Land

	Direct and Indirect	Population and Income Induced	Total
Employment (jobs)	10.5	6.5	17.0
Personal income ($1987)	271,000	92,000	363,000

Table 1b. Distribution of Employment Effects among Economic Sectors

Economic Sector	Direct and Indirect	Population and Income Induced	Total
	(%)		
Farm	65	0	40
Nonfarm			
Agricultural services	16	0	10
Construction	2	10	5
Manufacturing	2	5	3
Transportation, Communication & Public Utilities	1	3	1
Trade	7	26	15
Finance, Insurance & Real estate	1	10	4
Services	6	31	16
Government	0	15	6
	100	100	100

sults of an econometric model, explicitly includes the economic impacts of outmigration. An area with a small economic base, such as La Paz County, cannot absorb the labor force released from the agricultural industry as a larger economic area could. Thus, the number of outmigrants (relative to the number of agricultural jobs lost) is substantial. This outmigration generates additional economic impacts, particularly in the construction and real estate industries. All but the most sophisticated input-output models do not explicitly account for economic impacts of outmigration.

Fiscal Impacts

Table 2 presents estimates of revenue impacts for the City of Parker, for La Paz County government, and for other local governments in La Paz County. Estimated revenue impacts for Parker are $2,564 for each 1,000 acres of retired farmland. Half of this impact is attributable to the decline in sales (Parker has a 2% local sales tax rate). "Other" revenues to Parker include miscellaneous revenue items, such as business license taxes, licenses and permits, fines and forfeits, etc. There is no local property tax in Parker.

La Paz County government is impacted primarily through reductions in property taxes and state-shared sales taxes. Other revenues for La Paz County government include the auto lieu tax, licenses and permits, charges for services, fines and forfeits, etc. The "direct" property tax effect is the potential property tax lost to local communities in La Paz County if land (or a land leasehold) is purchased by another municipality because, according to the Arizona constitution, one municipality cannot be required to pay taxes to another. However, this impact may be zero if farmland is purchased by private parties or if the purchasing municipalities make voluntary payments in lieu of property taxes to local governments in La Paz County.

Over 100,000 acres of deeded land and 300,000 acres of leased land have been earmarked for water farms on properties entirely or partially within La Paz County (table 3a). Much of this land is grazing or raw desert land rather than irrigated farmland. However, nearly 50,000 acres of irrigated farmland is involved, land which currently grows an assortment of low and high-valued crops (table 3b). While it is not clear how long farming will continue on the irrigated acreage because water will not be physically transported from many water farms for decades, most land will be retired within a few years.

To put the present analysis into context, we assume that the roughly 40,000 acres of irrigated farmland lying entirely within La Paz County are retired at some point in the future. Retiring 40,000 acres of farmland causes 340 jobs to be lost, which represents 13.6% of La Paz County's 1987 employment. The personal income loss represents 9% of La Paz County's 1987 income.

The estimated revenue impacts imply that the City of Parker will lose approximately 5% of their non-utility revenues if 40,000 acres are retired. The county government of La Paz will lose approximately 6.4% of its revenues if the direct property tax effect is included. Without that direct effect (assuming nonmunicipal purchasers or in-lieu taxes), the county government is estimated to lose approximately 5.4% of its rev-

Table 2. Estimated Revenue Impacts (1987 Dollars per 1,000 Acres of Retired Farmland)

	City of Parker	La Paz County	Other Local Governments	Total Governments
Direct property tax		1,824[a]	5,383[a]	7,207
Indirect & induced property tax		3,279	9,686	12,965
Sales tax	1,255			1,225
State shared sales tax	166	2,320		2,468
Highway user revenue fund	238	553		791
Lottery funds	26	0		26
Other	879	3,541	[b]	4,420
Total	2,564	11,517	15,069	29,150

[a] This category applies only to the degree that municipalities purchase land and refuse to make voluntary in lieu payments to the local governments in La Paz County.
[b] Impacts on other revenue categories for other local governments were not considered, e.g., the reduction in state aid to schools associated with reduced enrollment.

Table 3a. Pre-Purchase Land Uses for Water Farms within La Paz County

Water Farm	Land Uses
Birmingham	5,618 acres of mostly raw desert
BJ Ranch	191,180 acres are grazed; the remaining 2,963 acres are farmed, with 1,737 acres in cotton
Cibola Valley Immigration District	4,600 acres irrigated agriculture
Crowder-Weiser Ranch	Use of 7,670 acres unknown; 2,388 acres irrigated, 1,117 acres undeveloped, 2,746 acres grazed
Five landowners	1,300 acres of mostly irrigated farmland crops
Fullmer Ranch	2,751 acres of irrigated agriculture, 1,210 acres raw desert, 138,544 acres used for grazing
Harquahala Valley Immigration District	24,000 acres of irrigated agriculture
Lincoln Ranch	800 acres irrigated crops including sod, cotton, fruits, and vegetables; 240 acres are grazed
McMullen Valley	1,200 acres of pecan and pistachio orchards and an additional 3,725 acres of cotton
Planet Ranch	2,400 acres of alfalfa
Ranegras Plain	22,950 acres of raw desert, 2,000 acres of cotton, 10,550 acres grazed

Table 3b. La Paz County Water Farm Acreage by Land Use

Land Use	Acreage	Percent
Irrigated agriculture	48,127	10.7
Unirrigated grazing land	343,260	76.3
Raw desert/abandoned farmland	50,970	11.3
Unknown land uses	7,670	1.7
Total water farm acreage	450,027	100.0

enues. The other jurisdictions will lose 12.8% with the direct property tax effect and 8% without it.

Several important points should be made about the estimated impacts presented in this article. First, all impacts do not occur immediately. It may take five or more years for impacts to work their way through the local economy after a farm is retired. For example, property values tend not to fall immediately when demand for housing falls. Rather, property owners tend to hold onto the property, unable to sell it, until the "real" value erodes via inflation. Thus, the indirect property tax impacts occur through reductions in real property values over time.

Second, the impacts do not occur evenly throughout La Paz County. The impacts, relative to the size the local economy, will be much larger in the eastern part of the county, which is almost completely dependent on agriculture. Although agriculture is important throughout the county, the economic base of the western part of the county includes tourism and sales to residents of the Colorado River Indian Reservation.

Third, we have not analyzed any positive aspects of water transfers, specifically impacts of spending associated with farm purchases and construction of transport infrastructure and impacts on areas of import. It is assumed that, once bought out, little or none of the purchase money will be respent in La Paz County. In addition, we are not viewing rural-to-urban water transfers as a zero-sum game for the state as a whole. The focus of this study is limited to the impacts in the areas of origin only.

Impacts on Future Development

The estimated impacts described above do not take into account the potential foregone growth that may be associated with either water transfers or the purchasing of water farms in La Paz County. For example, land that is used solely for water farming may be unavailable for development. The scarcity of deeded land in La Paz County and the fact that water farms located near the CAP canal also are located near the interstate highway and railroad make availability of developable land a concern.

In addition, there is an unquantifiable water "image" that is important for attracting business. Maintaining an image of having adequate water supplies has prompted Arizona businesses to advertise that "urban Arizona has no water shortage," a claim now being backed up by purchases of water farms. Residents of both rural and urban communities tend to view as desirable those community attributes that describe

where they live (Nunn and Urban). Therefore, one identified cost associated with rural-to-urban water transfers is that transfers threaten valued rural cultures and lifestyles (Nunn and Ingram). However, residents of La Paz County appear to be more concerned about lost opportunities for growth and development than about threats to their current lifestyle. Lack of safeguards or requirements to reserve water for use on the purchased land may make La Paz County a very unattractive location for development. Any economic growth that would have occurred but for the water farming activity represents additional, unquantified losses.

A survey of 317 community leaders in twelve water-importing and exporting areas of Arizona, New Mexico, and Texas was designed and administered in an attempt to better understand concerns about various nonpecuniary threats to rural areas of origin (Ingram). The survey contained eleven multipart questions that solicited views on who are the winners and losers in water transfers, which types of losses are most serious, and the degree to which these losses can be mitigated or compensated. One principal finding was that 93% of the respondents in La Paz County agreed with the statement, "The losses to the community associated with the transfer of water are of such a nature that they cannot be compensated," as did a majority of respondents in the Phoenix and Tucson areas (Oggins).

Additional findings of the survey include perceptions that certain groups, including government officials, attorneys, water utilities, and various water experts tend to gain when water is transferred, while private well owners, indigenous groups, future generations, and small farms tend to lose. The degree to which respondents believe that market solutions generally increase public welfare depends upon the occupation and role of the respondent, with city officials and members of the Chamber of Commerce most confident in market solutions and farmers, agriculture-related businessmen, and members of school boards and PTAs least confident.

There also were differences in the degree to which various types of respondents believe that urban water conservation is a viable alternative to water transfers and the effectiveness of various potential compensation schemes. In general, mitigation/augmentation approaches that put authority over water transfers or up-front money in the hands of local government were preferred over other approaches that involved other entities, payments to individuals, or payments only at time of physical transport of the water.

Conclusions

Impacts of rural-to-urban water transfers that result in loss of irrigated agriculture do not result in significant economic impacts when viewed from a statewide perspective. When viewed from a county level, such impacts are substantial but not devastating. Similarly, fiscal impacts are real but not catastrophic. However, the impacts tend to be highly concentrated because the factors which make particular parcels suitable water farms can result in geographic clustering of purchases. Therefore, if water transfers result in the levels of economic gain claimed for them, strong arguments can be made for mitigation and compensation. However, some of the more important potential losses associated with transfers, including loss of autonomy and reduced options for future development, can be neither estimated nor compensated.

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The Economic Impacts of Agriculture-to-Urban Water Transfers on the Area of Origin: A Case Study of the Arkansas River Valley in Colorado

Charles W. Howe, Jeffrey K. Lazo, and Kenneth R. Weber

The development of new water supplies has grown increasingly costly, both in financial and environmental terms. Public values related to instream flows, preservation of natural areas, and wildlife have increased sharply relative to the values of traditional water uses. In such a setting, reallocation of existing supplies becomes increasingly attractive, and water transfers have been hailed as the solution to western U.S. water shortages (e.g., Anderson, Saliba and Bush, Howe et al).

A major U.S. Geological Survey-funded study (MacDonnell et al) has found frequent water transfers in several western states (Colorado, New Mexico, and Utah) but infrequent transfers in other states (e.g., California and Wyoming), the frequency being strongly affected by the institutional structure for effecting transfers and the pressure on water supplies. A glance at water use data (U.S. Geological Survey) shows that 80% of all water diversions and nearly 90% of all water consumption in the western United States occur in irrigated agriculture, strongly suggesting that small percentage reallocations from agricultural to nonagricultural uses could satisfy growing nonagricultural water demands for decades.

Some economic studies suggest that economic impacts of rational transfers from agriculture will be minimal. Popular perceptions are more pessimistic and foreboding: "draining the lifeblood of farms" or "tantamount to agricultural suicide" (*Rocky Mountain News*). Some resolution of these contradictory facts and perceptions is called for.

The Benefits and Costs of Water Transfers

The buyer and seller of water in a market transaction presumably gain from the transfer, but other parties can be affected positively or negatively. The most obvious are those experiencing externalities from the transfer, i.e., positive or negative physical impacts on their production or consumption activities that are not compensated through the market. Negative externalities from transfers include reductions in water quality, in water available because of reduced return flows, and in instream values such as recreation and aesthetics. Positive externalities can occur downstream from the new use because of better water quality or increased return flows.

Protection of third parties from negative externalities of transfers is at least partly provided by the laws and institutions governing transfers in the western United States. For example, downstream parties are protected from reduced return flows by regulations that limit the transfer to the prior consumptive use (in contrast to the amount diverted). Transfers from a particular stream may be limited if water quality deterioration causes harm to remaining users. However, recreation, wildlife, and aesthetic uses typically are not protected. As Hartman and Seastone pointed out in 1970, positive externalities are not accounted for in western U.S. water administration, creating a bias against transfers. In sum, important positive and nega-

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tive externalities are not taken into account in water transfer processes.

Parties indirectly linked through the market to the sale or purchase of water also gain or lose in ways that are validly included in national economic efficiency calculations (e.g., MacDonnell and Howe). For example, there may be transitory or permanent income losses to factors of production in sectors with backward or forward linkages to irrigated agriculture. In the presence of persistently depressed rural conditions, factors of production left unemployed in agriculture, in agricultural supplying activities, and in agricultural processing activities can be idled for long periods, leading to real national efficiency losses. Substantial economic and psychological costs are incurred even by those factors that successfully move to new occupations. Such costs typically are ignored in comparative statics analyses, often erroneously being labelled "pecuniary" gains or losses.

Naturally, the apparent importance of these indirectly incurred costs depends on the "accounting stance" employed by the analyst. In the area of origin, indirect employment and income losses can be persistent and of great importance. At the state level, both direct and indirect losses of income and employment in the area of origin may be offset by gains in the importing areas. At the national level where the agricultural losses easily can be made up by expanded production in other states, the losses in the area of origin may appear totally inconsequential.

The state laws and institutions governing water transfers typically overlook the indirect economic costs imposed on the area of origin. Microeconomic and regional analyses suggest that the severity of economic impacts on the area of origin will differ according to (*a*) whether or not the new use is inside or outside the economic area encompassing the area of origin, (*b*) the economic vitality of the area of origin, (*c*) whether or not the water sales proceeds are reinvested in the area of origin, and (*d*) the strength of the backward and forward linkages between irrigated agriculture and supplying and processing sectors.

Description of This Study

This is a case study of a seven-county reach of the Arkansas River in southeastern Colorado, an area from which a large amount of agricultural water already has been transferred to urban uses and for which there is the prospect of even larger future transfers. The study is not a complete evaluation of these transfers, but only of the negative economic impacts caused directly and indirectly by the reductions in irrigated agriculture. The negative impacts are measured in terms of employment, personal income, value added, and population for the area of origin and for the State of Colorado.

The Arkansas River Valley of southeastern Colorado was chosen as an area where the impacts of transfers could be severe because it has (*a*) a dry, highly variable climate with mean precipitation of only eleven inches; (*b*) little opportunity for agriculture in the absence of irrigation; (*c*) geographic isolation from other farming areas, making the substitution of imported supplies for local production costly; (*d*) clear backward and forward linkages to suppliers and processors for a significant portion of irrigated outputs; (*e*) a historically marginal, depressed economy; and (*f*) heavy agricultural indebtedness. Table 1 provides an outline of the region's land, farming, irrigated areas, and cropping patterns.

Roughly 30% of all crops are irrigated, but only 2.4% of irrigated crops are vegetables, fruits, or other specialty crops that typically require further processing. The Arkansas Valley is famous for its Rocky Ford melons, which are crated and shipped across the country. Some melons also are grown for highly valued seed. Other specialty crops that receive extensive processing in the valley are onions, tomatoes, and flower seeds. These crops have strong forward linkages to processing. The irrigated feed grain and hay crops support the feedlot industry of the region.

Table 1. The Arkansas Valley Study Area: Baca, Bent, Crowley, Kiowa, Otero, Prowers, and Pueblo Counties

	Acres
Total land:	7,661,440
Land in farms:	5,934,856
Land in farms with irrigation:	349,815
Farms with groundwater sources:	121,068
Farms with direct flow irrigation:	228,747
Nonirrigated field crops	749,357
Irrigated field crops	300,709
Vegetables	6,902
Fruits and specialties	536
Total crops	1,057,504
Total irrigated crops	308,147

Source: 1982 Agricultural Census of the United States.

Historical Transfers and Their Impacts

A water transfer does not just happen at an instant of time with its full effects experienced instantaneously. Water sales and subsequent transfers may be negotiated over several years. Once a farmer or a ditch company decides to sell, cropping patterns, land maintenance, and productivity begin to change. Water may be held on the land by court decree for revegetation or may be partially left on the land because the buyer does not yet need it. There is no such thing as a clean-cut water transfer. Subject to such caveats, table 2 presents the significant historical agriculture-to-urban transfers.

Vegetable and specialty crop acreages remained quite steady over time for the valley as a whole. Most of these crops were grown under contract to shippers and processors, and there was always a waiting line of growers wanting contracts. Thus, over the historical period analyzed, the high value, forward-linked horticultural crops always were "bumped" onto new lands as old lands were dried up. Thus, historically there were no vegetable/specialty phase-outs and no forward linkages due to those crops. There is no evidence that the phase-outs of feed grains, hay, and the irrigated pasture held back the expansion of feed lots over the historical period from 1955 (Otero Ditch sale) to 1985 (Colorado Canal sale). Thus, forward linkages were judged to be absent in this historical period.

It was our intent to use the combination econometric/input-output Colorado Forecasting and Simulation Model (COFS) of the Center for Economic Analysis, University of Colorado, Boulder, to analyze the temporal pattern of impacts of both the historical and the potential future transfers. COFS is a REMI model that has been elaborated over nearly a decade to include a demographic submodel and analyses for substate regions of which the Arkansas Valley is one. Unfortunately, it was not possible to recalibrate COFS for the earlier period, so a statewide input-output approach was used for the historical analysis, an IMPLAN model based on the 1977 BEA I-O model, updated to 1982 dollars. The results of the analysis are presented in table 3.

The loss of state net income of $53 per acre-foot certainly was more than offset by cost-savings to the cities buying the water because the cost of developing new water has risen to more than $2,000 per acre-foot. Again, however, the incidence of the income losses will be largely in the area of origin, while the cost saving (and consequent increase in expenditure on other goods and services) will be in the buying cities. The same can be concluded regarding the incidence of losses and gains of government revenues.

In sum, the statewide direct and indirect employment and income losses stemming from historical agriculture-to-urban transfers appear to have been small relative to the costs of alter-

Table 2. Historical and Potential Transfers

Ditch	Year	Acres	AF Cons. Use
Historical			
Otero	1955	4,500	9,000
Las Animas Town	1971	1,900	5,800
Booth Grove Orchard	1972	1,447	2,894
Hobson	1972	275	1,488
Colorado Canal[a]	1985	40,267	80,534
Total historical transfers		48,389	99,716
Percent of 1982 base		13.6	14.0
Potential			
Rocky Ford (majority)[b]	1990	4,100	9,270
Keesee	1991	1,400	2,925
Rocky Ford (minority)	1994	3,800	9,500
Las Animas Cons. & Ext.	1998	6,950	17,375
Holbrook Mutual	2001	9,775	24,438
Fort Lyon	2003	61,100	152,750
Amity Mutual	2007	22,610	56,525
Bessemer	2010	9,725	24,313
Catlin	2013	9,750	24,375
Total potential transfers		129,210	321,470
Total historical and potential		177,599	421,186
Percent of 1982 base		57.6	62.1

[a] Includes earlier Twin Lakes transfers for purposes of this analysis.
[b] Rocky Ford majority water has been sold but not transferred.

Table 3. Statewide Negative Direct and Indirect Impacts of Historical Arkansas Valley Transfers (1982 dollars)

Reductions in:
Employment = 157 = 1 job per 308 acres
State net income = $5,290,000 = $53 per A.F. Cons.
Local/state government revenues = $506,350 = $5 per A.F. Cons.

native ways of getting water for the urban areas. However, the incidence of the costs is upon the rural areas, while the benefits accrue largely to the urban buyers.

Table 4. Future Transfers: Percent Reduction from Baseline Projection in Year 2020

	Arkansas Valley		State	
Scenario	3	5	3	5
Farm employment	10.1	21.0	1.2	2.5
Total employment	0.8	1.6	0.0	0.1
Population	0.2	0.3	0.0	0.0
Value added—farm	10.0	21.1	1.2	2.5
Value added—total	1.4	2.5	0.0	0.1
Personal income—total	1.1	1.6	0.0	0.1

Note: 0.0. Indicates negligible differential (<0.5%).

Potential Future Transfers and Their Estimated Impacts

Information regarding future transfers was obtained from transfer applications already filed and from discussions with water users and ditch company officials (see table 2). The occurrence and timing of future transfers is highly speculative. Most water users and water officials agreed that the potential transfers listed in table 2 are likely.

Several scenarios were run through the COFS model for these future transfers, each differing in the canals phased out and the extent of assumed forward linkages. Scenario 3 reported below assumed all the potential transfers indicated in table 2, including the vegetable and specialty acreages when the last two canals are phased out (all vegetable and specialty crops were assumed to be "bumped" onto the lands of the last two canals). Scenario 5 reported below is the most severe scenario and assumes all those transfers plus partial forward linkages of vegetables and specialty crops to food processing (based on percentages sold fresh and percentages sold under contract for processing) plus an 80% phase-out of feedlots in response to increased costs of importing feed grains and hay. The results are reported in table 4 in terms of percentage decreases from the baseline COFS projections (no water transfers) to the year 2020.

These results show that farm employment and value added in the Arkansas Valley are severely impacted under both scenarios 3 and 5, the latter producing 21% reductions from the projection without transfers. The percentage decreases in total employment and value added, however, are much smaller. At the state level, these changes and the changes in personal income sink to insignificance.

The temporal pattern of negative impacts (not shown here) remains negligible for the Arkansas Valley until the Fort Lyon Ditch is phased out in 2003 (see table 2). The Bessemer and Catlin transfers result in very large local employment and income impacts because they have been assumed to carry all the vegetable and specialty crops.

Conclusions

Judged at the state level, none of the water transfer scenarios analyzed results in significant losses to the state agricultural or general economy. Historical transfers appear to have imposed total costs in terms of employment and personal income that would easily have been offset by cost savings and alternative expenditures in the importing urban areas. The same conclusions hold for the prospective transfers.

However, the incidence of the costs is always on the area of origin, while the benefits accrue to the area of new use. If water is transferred from agriculture to expanding uses in the same economic region, then many of the negative effects are offset locally. Most of the time, however, transfers are to uses outside the agricultural economic area. In such cases, significant uncompensated costs are imposed on the local economy. These effects are exacerbated by the use of sales proceeds to repay heavy farm debt and the absence of local investment opportunities for these funds.

The results thus imply that states should not fear water transfers: transfers will not wreck ba-

sins of origin nor state economies. The results do imply, however, that transitional assistance is warranted to help those parties suffering uncompensated externalities and indirect displacement by transfers. Areas of origin warrant assistance.

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The Impacts and Efficiency of Agriculture-to-Urban Water Transfer: Discussion

Norman K. Whittlesey

The paper by Colby is well written, thoughtful, and provocative. She reviews the record of water exchanges in the West, focusing on the policy-induced transactions costs (PITC) necessary to obtain state approval of proposed water rights exchanges. These costs result from considering externalities that otherwise would be ignored by water buyers and sellers negotiating in their own best interests. But I have a concern that we recognize only the economic activity that is capable of self-representation in this process. By defining competition in this manner, we may fail to recognize significant social uses and values of water, particularly those associated with nonappropriated uses on many flowing streams. Colby states that the "public interest" is rarely used to contest a proposed transfer.

Colby correctly demonstrates the optimal PITC as exactly equivalent to a Pigouvian tax representing the externality costs associated with a water right exchange. However, the *WTP* curve, as derived, will not include the externality benefits associated with the alternative uses of water. This curve should be shifted upward to reflect these benefits and to indicate an optimum level of water transfer. Alternatively, there is no reason to expect the *SMC* curve always to lie above the *PMC* curve if it reflects both positive and negative externalities of the exchange. In any case, a water transfer should take a balanced position toward the externality benefits and externality costs of the exchange.

Colby's major conclusion is that transactions costs generated by state regulation of water transfers out of agriculture may be lower than socially optimal. My response is that if a major portion of transactions costs goes to engineers, hydrologists, lawyers, and economists to define water rights on a case-by-case basis, there must be great inefficiency and potential inequity in the process. In the interest of efficiency, we must be able to define the transferable interest of an irrigation water right. In most cases, this can be accomplished without extreme difficulty. All direct uses of water must be protected. But the pure economic interest that is secondary to direct water use probably should not be allowed to have an interest in the water right transfers. Transferring water to a higher-valued primary use should always result in an equally higher secondary economic value. The argument becomes one of distribution or political constituency but not economic value.

The paper by Charney and Woodard describes the local economic impacts from water farming in Arizona, wherein municipalities purchase agricultural land to obtain the associated water rights. The implication is that the land will eventually be retired from farming and the water (right) moved outside the local region for nonagricultural use. Charney and Woodard use a survey approach to estimate the economic impacts of the water transfer. I have some major concerns about this paper.

The first deals with the level of economic activity claimed to be associated with irrigated agriculture in a local economy. The levels of employment and income used for local economic impact are much higher than expected. Compared to similar measures of primary and secondary employment effects from irrigation reported by Howe, Lazo, and Weber and many others, the values used by Woodard are unexpectedly high for state-level impacts. For county-level impacts they are quite excessive.

I am also bothered by the implication that economic impacts are estimates of economic benefit or cost. The impacts described are similar to those measured by an input-output model. They indicate nothing about the net benefit (welfare) derived from any level of activity or change in activity level. If, as implied, land purchases are made in advance of the actual decline in agriculture, the local economy should derive

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a considerable benefit from the increased capital liquidity in the region. No measure of this benefit is considered.

Properly, one must estimate the opportunity cost of labor and capital in order to determine the change in net economic benefit from a reduction in irrigated agriculture (Hamilton et al.). Then, the net benefit changes are a result of temporary disequilibria in the labor and capital markets. Not only are the net benefit changes going to be a small portion of total economic impacts, they are short run in nature, disappearing once a new equilibrium is achieved in the capital and labor markets. This type of analysis should be carried out for a long period, say 50 years, using a proper discount rate, in a complete "with versus without" framework, and the accounting stance must be carefully defined. None were properly done in this case. The only conclusion that can be derived from this analysis is that the local economy will probably be smaller after the change than before. Nothing can be said about whether the remaining or previous populations will be better or worse off.

The paper by Howe, Lazo, and Weber uses an input-output model to describe the past and future potential impacts on the Arkansas Valley region of Colorado imposed by water transfers from agriculture to municipalities. The authors are candid in stating that they describe only the negative impacts imposed on local agriculture by the water transfer. Consequently, there is no measure of whether the remaining agriculture in the region or state is better or worse off after the water transfer.

At the risk of being repetitive, let me conclude. These and other similar studies are too quick to describe the negative impacts of water transfers on a local economy while providing no measure of the positive externalities that may come from the transfer. Because of the model used, they are not useful in describing the social welfare impacts of water markets. They may even fuel the inefficient state policies controlling water transfers described by Colby. I would urge practitioners of impact modeling to be more careful in describing the useful limits of their results. We cannot profess our good intentions and expect the politician or policy maker to understand how to properly employ our work. Such results are useful for planning the adjustments to water exchanges but may be very misleading if not carefully presented.

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The Impacts and Efficiency of Agriculture-to-Urban Water Transfers: Discussion

Richard L. Gardner

The three papers demonstrate a rapid evolution in thinking about water marketing, from recognizing its potential to improve efficiency, to noting institutional impediments and calling for their removal, to reassessing the need to correct market failures in water transfers. This evolution has largely occurred in the last decade and parallels the transition from water development to an era of water reallocation. Hence, we have papers today by Charney and Woodard; and Howe, Lazo, and Weber that focus on the local economic impacts of water transfers out of agriculture, while Colby argues water markets fail to address public goods and externalities and that the costs imposed by state water right transfer policies help close the gap between private and social costs and actually improve water allocation patterns.

The Colby paper is provocative, well written, and contains important empirical data on transactions costs. Colby's hypothesis is personally appealing because I believe that water markets fail not only because of physical externalities of return flow interdependencies, to pecuniary externalities of secondary economic impacts, and to public good aspects of instream uses, but also because water markets fail to meet the competitive market requirements of complete information, homogenous product, and atomistic, profit-maximizing participants (Gardner). Thus, true, functioning water markets are rare. Instead, voluntary, negotiated transfers are the rule, aided in places by market-like entities.

Although many constraints on water transfers were purposefully developed to address perceived market failures, two other thoughts emerge. First, the implicit notion in Colby's paper that large transaction costs are inherently good should be dispelled. Administrative efficiency remains a policy goal even if the inefficiencies convey a positive externality. Excessive delays, tedious case-by-case analysis, and expensive legal costs can be streamlined. For instance, Idaho presumes the consumptive use for irrigation to be the amount required to grow alfalfa in the region, thus eliminating lengthy arguments over historic consumptive use. In contrast, water marketing in Idaho is needlessly penalized by an administrative rule that water rightholders who rent to downstream users from the Upper Snake Water Bank lose priority in refilling their reservoir space *vis-à-vis* equal rightholders who use their water to irrigate their lands. Although compensation of damages is not a required use of Pigouvian tax revenues, it would certainly be preferred to investment in bureaucracy or litigation. Colby should more carefully differentiate between those procedures designed to correct market failures versus legal or administrative flaws in the transfer system.

Colby's implicit assumption of a competitive market structure was another concern. Rarely do many buyers and sellers act in a local water market at the same time. Marketing activity often accelerates for a time to accommodate the water needs of a single purchasing entity. The paucity of buyers may be aided by another type of market failure—natural monopolies for municipal water supply or hydropower production. A textbook example of a monopsony occurs in the Upper Snake Water Bank where Idaho Power Company accounts for 81.2% of all rentals over the last twelve years. Sellers may limit the number of actors on the supply side by participating in water markets from the wholesale level of irrigation districts rather than as individuals.

The theory of bilateral monopolies applies to negotiated water transfers in such imperfect market settings. The equilibrium price and quantity of mutually beneficial sales are indeterminate; both parties will try to capture the economic rents available from the transaction. However, all three papers would seem to agree that the transaction space between the irrigator's

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reservation price and the buyer's willingness to pay for a new use is generally quite large and well above transaction costs. The seller's reservation price may be larger than the marginal value of water in irrigation because of noneconomic values (Oamek, Mumme and Ingram), and that price may fluctuate with the seller's expectations of his ability to sell to a higher-valued use (Gardner and Miller).

The Charney and Woodard and Howe, Lazo, and Weber papers are more narrowly focused on the social and economic impacts to basins-of-origin when significant amounts of water are transferred from agriculture to urban uses. Both contain a case study. Howe, Lazo, and Weber evaluate theirs with an IMPLAN input-output model, Charney and Woodard with an econometric impact model aided by partial analysis of the agriculture-related sectors. A key difference is that Charney and Woodard's model retires high-valued crops in proportion to the county crop mix, while Howe, Lazo, and Weber more realistically assumes higher-valued crops will shift to remaining acreage. Because of this assumption and considering that their model measures impacts to a single county, Charney and Woodard's employment and personal income impact estimates seem high compared to Howe, Lazo, and Weber or Keith and Glover. Further, Charney and Woodard should distinguish more carefully between secondary impacts and the much smaller secondary benefits which might be subject to mitigation (Keith and Glover).

Both studies conclude that, while the adverse impacts of such transfers to the regional economy are small, there can be significant impacts to a local economy, and the incidence of costs tends to accrue to different sets of individuals or government entities than the benefits. Both papers call for some form of mitigation or transitional assistance to local affected parties.

Curiously, neither paper offers policy alternatives that might address their findings. Transferring the rights to use a flow resource seems analogous to extracting an exhaustible resource (Metzger), particularly for "mined" groundwater in Arizona. Such transfers forego opportunities to use that resource in the future. The marginal intertemporal opportunity cost is more commonly called the user cost, and this is the theoretical underpinning for mineral severance taxes. The rationale for taxing water transfers seems even stronger because, while the extraction of a mineral resource creates jobs in the present, the extraction of water from a region causes a local loss of employment. Intriguing legislation proposed in Colorado several years ago would have charged a "transfer tax" equal to five times the lost property tax whenever water was transferred out of the area from agriculture. The proceeds would have gone to county "economic augmentation funds," thus providing monies to diversify the local economy in adjustment to the agricultural loss.

At the core of all three papers lies the notion that maximizing economic efficiency is not society's only goal. Other cultural and social values, such as maintaining the opportunity for a rural lifestyle and preserving environmental quality, must be considered. Advocates of maximum economic efficiency through unencumbered, interbasin water transfers should also remember the implicit assumption in neoclassical theory that the current income distribution is appropriate. Budget constraints will have a very real impact on the willingness to pay for water, especially for aesthetic and environmental uses. Water transfers will certainly have distributional impacts but, as Howe, Lazo, and Weber note, they are not at all likely to increase social welfare. To quote two respected legal scholars, "While a society fashioned solely by economists might be very efficient, it is unlikely that one would choose to live there" (Dumars and Tarlock).

Local economic impacts come under the legal heading of "public interest," which most states must consider before approving water transfers. This concept is rarely well-defined. Consider an Idaho definition of the local public interest as "the affairs of the people directly affected by the proposed use." Who are those directly affected? It is not far from Rocky Ford to Pueblo, where new jobs are being created. It is farther from La Paz County to Phoenix, and it is a long way from the Upper Colorado or Columbia River Basins to Southern California. Local perceptions of economic loss seem to vary directly with the distance of the transfer as the positive secondary impacts of the new water use are lost to the basin-of-origin.

I agree with Colby that, while urban transfers will remain a threat to the public interest of irrigated agricultural areas, there is increasing consideration of environmental issues. Water rentals in Idaho have been used for such innovations as maintaining trumpeter swan habitat and meeting the water quality standards for a paper mill in a drought year. A pilot rental program will soon provide rental water for improved spring flows for anadromous fish, and proposals to list salmon as endangered species could precipitate additional transfers within the Snake/Columbia system.

In most states the public interest could be enhanced by increasing minimum stream flows for instream uses. Here, the state is really trying to estimate the vertical summation of the demand for a public good, subject to the availability of unappropriated water. States would do well to allow private parties to purchase consumptive water rights for dedication to instream use. I disagree with Colby that individuals should be allowed to file on unappropriated waters. This may lead to frivolous claims on all available water.

Though riddled with imperfections, I remain convinced that market mechanisms have the potential to continue to improve water management and that public acceptance is slowly increasing. In Idaho two more water banks have formed recently and a third is likely to emerge from a reserved water rights settlement. The three papers in this session highlight the need to recognize the limitations of water marketing and at the same time the need to look for barriers to water transfers that are not intended to correct market failure. In the context of this session, the cliche "Don't throw the baby out with the bath water" takes on new meaning.

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Methodological and Empirical Challenges in Analyzing Structural Change in U.S. Food Systems
(Clement E. Ward, Oklahoma State University, presiding)

Economics of Consolidation in the Beef Sector: Research Challenges

Wayne D. Purcell

The beef industry experienced unprecedented structural change during the 1980s. Four-firm concentration ratios in boxed beef production jumped from 51% in 1979 to 79% in 1988. For steer and heifer slaughter, the increase was from 37% in 1979 to 70% in 1988.

In 1980, congressional hearings were conducted regarding the potentially negative dimensions of market power by meatpackers. Concentration levels had increased during the 1970s. Concern was sufficient to prompt the introduction of two pieces of proposed legislation, both of which would have limited the size of packing operations. During the hearings, testimony was replete with dire predictions of what would happen to industry performance if concentration were to increase still further. Parker testified that the research literature documents rapid increases in prices and in profits as the four-firm concentration moves up from 40% to 60% and higher.

Viewed in the presence of the content and orientation of those congressional hearings, the happenings later in the 1980s appear incomprehensible. If the important threshold in terms of the four-firm concentration ratio is around 40%, why was the massive consolidation of the beef sector during the 1980s allowed by the regulatory authorities? What research methodology was brought to bear on these issues? Is it adequate? The answers to these related questions are not apparent, but they are clearly important. If the decisions by the regulatory authorities during the 1980s were not based on solid economic research, then important issues confront the profession. Either the research methodology must be modified or the empirical results of our research were ignored.

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The objective of this paper is to explore the economics of the consolidation in beefpacking, to look at why it occurred and why it was allowed to occur, and to draw inferences about our research efforts. The perspective offered is that of a marketing economist looking ahead to an uncertain future for the beef sector in the 1990s.

Market Power versus Superior Efficiency

A survey of the literature starts to explain the events of the 1980s. During the 1950s, 1960s, and the early 1970s, the regulatory agencies were aggressively enforcing the various antitrust statutes. The basic tenet of the Structure-Conduct-Peformance (SCP) paradigm initially popularized by Bain, that a high level of market concentration leads predictably to socially undesirable performance, was widely accepted. Across the major antitrust statutes (Clayton Act, Federal Trade Commission Act, Sherman Act) the Federal Trade commission (FTC) and the Justice Department (Justice) brought 290 cases in the food system in the 1956–60 period. By 1976–80, the total was down to 64 cases (Marion 1986a, p. 378).

It was a switch to the so-called Chicago School of thought that ushered in the change. Presented by Demsetz, the Chicago School argued that consolidation and concentration lead to increased efficiency. This "superior efficiency" argument was offered to counter industrial organizaton economists who subscribed to the SCP paradigm and who argued that concentration occurs in a search for market power.

The theme underlying the Chicago School of thought was developed into the theory of contestable markets by Baumol, Panzar, and Willig in the early 1980s. Markets were seen as inherently competitive, and ease of entry and exit was

the economic force that blocked any significant departure from competitiveness. A firm could enter, earn temporary profits, and exit. To prevent such hit-and-run entry, incumbent firms must produce efficiently and earn no economic rent. If markets are perfectly contestable, the level of concentration is then irrelevant.

There can be little doubt that a major change occurred at Justice during the 1970s and early 1980s. Alarmed by the developments of the 1980s, the American Bar Association appointed a task force in early 1989 to examine the Justice Department's antitrust program. The task force report identified three reasons for the change to a more permissive policy (ABA, p. 8):

(*a*) The gradual but fundamental change in antitrust economic analysis which invited reconsideration of the wisdom of a number of previous antitrust decisions.

(*b*) The globalization of the American economy, which raised questions about whether a nationally oriented antitrust policy would hurt American businesses.

(*c*) The growing popularity of the "philosophy of deregulation," which led to skepticism about the ability of government to carry out an antitrust policy that would be beneficial.

The task force cited two cases in the late 1970s as evidence that the courts were starting to pay significantly more attention to the arguments involving economies of size and related efficiencies in acquisitions or mergers (*Continental TV, Inc.* vs. *GTE-Sylvania,* 433 U.S. 36, 1977; *Broadcast Music, Inc.* vs. *Columbia Broadcasting System,* 441 U.S. 1, 1979). The task force cited data documenting a continued decline during the 1980s in civil cases involving merger enforcement actions and/or antitrust enforcement actions. The average number of cases for 1979–83 stood at a relatively low 20.5 and declined even further to an average of less than 11 per year for the 1985–88 period.

The task force endorsed the use of economic analysis in deliberations about proposed mergers but also confirmed a continuing belief in the basic tenets of the SCP paradigm. They noted that, in spite of the Justice's 1982 and 1984 guidelines suggesting that proposed mergers are more likely to be challenged when concentration as measured by the Herfindahl Index (HHI) is high, very few of the almost 8,000 premerger notifications during the 1982–86 period were challenged.

In an early 1990 presentation, Sanford Litvack, a former member of the Justice Department Antitrust Division, agreed that Justice was largely out of business during the decade.[1] He noted that the emphasis was on criminal activity and that most mergers and acquisitions were allowed under the banner of increased efficiency. The 1984 merger guidelines, Litvack suggested, are largely ineffective because of two huge loopholes.

The first loophole comes in the form of market definition. Litvack notes that if you define the "market" broadly enough, then there will be no high level of concentration. For example, if the market is not defined in terms of boxed beef but in terms of all beef or all protein foods, then high levels of concentration in boxed beef are not seen as an enforcement issue.

The second loophole involves ease of entry. This is a basic tenet of the contestable markets theory and is closely related to the idea that all markets are inherently competitive and that there are no significant barriers to entry. Litvack was skeptical and, like Marion, criticized the theory as too simplistic (Marion 1986b). The ease of entry idea is built upon the notion that entry is free, that the entrant is just as cost effective as the incumbent firm, and that exist is costless.

It was in this environment of uncertainty and changing attitudes that developments late in the decade ushered in four-firm concentration ratios as high as 80 in boxed beef production. In 1987, for example, Excel (owned by Cargill) purchased Spencer Beef after the U.S. Supreme court overturned two lower court rulings that had blocked the merger in support of a suit by Monfort of Colorado. After the Supreme Court overturned the ruling. ConAgra purchased both Monfort and Swift Independent. The efficiency of large size was the cornerstone of those advocating the merger moves, and it was apparently to those arguments that Justice and the courts were inclined to listen.

A Stimulus for Change

Concentration increased throughout the economy during the 1980s. It happened in the airline industry, food retailing, banking, and energy. But concentration is generally considered a time-stable phenomenon, and it is unusual to see con-

[1] Presentation at the National Conference on "Structural Change in Livestock: Causes, Implications, Alternatives," conducted by the Research Institute on Livestock Pricing, Agricultural Economics, Virginia Tech, in Dallas, 22–23 Feb. 1990.

centration ratios double in less than ten years. Even if we assume that Justice and the courts would eventually approve every merger request, there had to be a stimulus behind all those requests in the beef sector. Decreases in demand for beef, starting in the 1970s, generated a powerful economic force that compelled some type of adjustment.

Highly structured econometric models that are not specified to pick up changes in the level of demand for beef have generated mixed results about changes in beef demand. Data requirements have also been a problem. Some of the models require a number of years of change before a statistically significant change can be confirmed. All this caused some confusion during the decade, but the most recent studies are starting to generate consistent results. In a study commissioned by the National Livestock and Meat Board, Ronald Ward found that demand for beef declined during the 1980s and continued to decline through 1988. In a February 1990 article, Choi and Sosin find evidence of structural change in beef demand, related to a preference change, that started in the mid-1970s.

In the presence of still-mixed opinions, it is instructive to look at the data. The data also provide a measure of the intensity of the shock that swept through the beef industry. Table 1 provides per capita consumption data (retail weight) and both nominal and deflated (CPI, 1982–84 = 100) prices of Choice beef at retail. During a period in which the overall price inflation reached annual rates in excess of 10%, the consumer refused to pay higher prices. Prior to 1988, the retail price of Choice beef had been in the $2.30 to $2.50 range since 1979. In inflation-adjusted terms, the problems are even more apparent. From 1979 through 1986, real prices had to decline over 30% to get the consumer to take what was essentially a constant per capita supply. When we consider that real consumer incomes trended higher during the period and that the prices of both pork and poultry increased relative to beef, it is difficult to avoid a conclusion of preference-related decreases in demand.

The decreases in demand rocked the beef sector. A herd liquidation that started in 1975 from a national herd of over 132 million head continued, with only short-term interruptions, into the 1988–90 period with the herd now under 100 million. At every level of the system, the price pressures emanating from the consumer level brought a need to get more efficient.

The record of accomplishment is impressive. Figure 1 shows beef production and January 1 inventories. In recent years, beef production has paralleled production of the late 1970s and early 1980s when the herd was 10% to 15% larger. But the increases in per unit output were not sufficient to offset the price pressures. A recent USDA publication by Shapouri et al. indicates that all producers except those producers with over 500 beef cows lost money consistently during the 1980s prior to 1987, when an accumulating reduction in supply levels pushed cattle prices higher.

With overall price inflation reaching double-digit levels in the early 1980s, the packers and processors were vulnerable to the demand-based price pressures. They had to become more efficient to offset the pressures or risk being forced out of business. Figure 2 indicates efforts to in-

Table 1. Per Capita Consumption and Price of Choice Beef at Retail, Actual and Deflated (CPI, 1982–84 = 100), 1970–89

Year	Per Capita Consumption	Retail Price	Deflated Retail Price
	(lbs. retail weight)	——— (¢/lb.) ———	
1970	84.4	98.6	262.0
1975	88.0	154.8	287.7
1977	91.4	148.4	244.9
1979	78.0	226.3	311.8
1980	76.4	237.6	288.4
1981	77.1	238.7	262.5
1982	76.8	242.5	251.3
1983	78.2	238.1	239.0
1984	78.1	239.6	231.1
1985	78.8	232.6	216.3
1986	78.4	230.7	210.4
1987	73.4	242.5	213.4
1988	72.3	254.7	215.3
1989	69.0	265.7	214.3

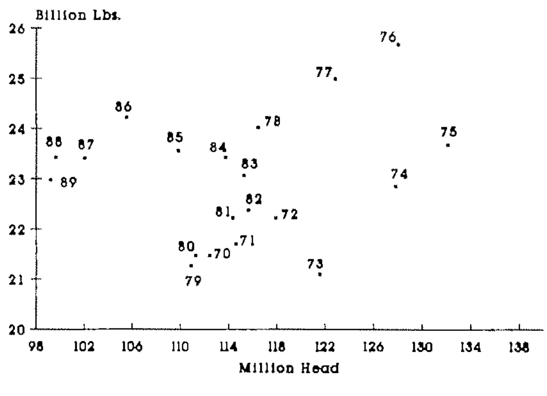


Figure 1. Commercial beef production related to 1 Jan. inventories, 1970–89

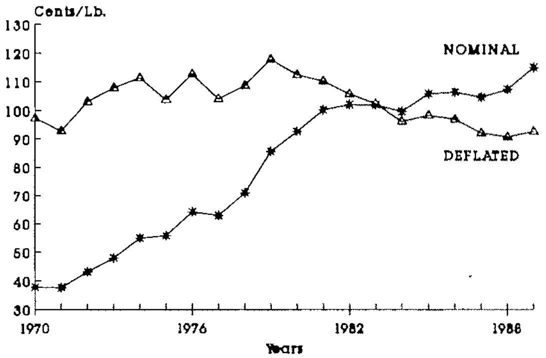


Figure 2. Nominal and deflated farm-retail price spreads for beef, 1970–89

crease efficiency were effective. The deflated (CPI 1982–84 = 100) farm-retail price spread declined significantly during the decade, suggesting the packers (or distributors and retailers) were either accepting reduced margins or were decreasing per unit costs significantly.

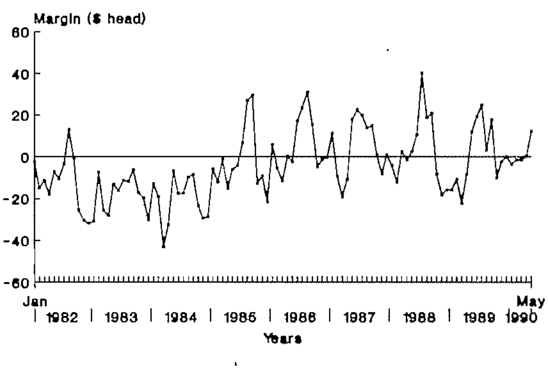
Figure 3 provides a plot of packer margins developed by the Helming Group by month from 1982 through early 1990. It appears that part of the significant reduction in the farm-retail price spreads early in the decade of the 1980s resulted from smaller margins at the packer level. Later in the 1980s, the data suggest packers were able to earn a slightly higher average margin, indicating that the continued decline in the farm-retail spread was at least partially caused by significant increases in efficiency at the packer-fabricator level.

Many economic forces were at work in the beef industry in the 1980s, but the problems on the demand side were arguably the most important. In an *ex post* context, it is clear that decreases in demand were a stimulus for change, for industry-wide adjustment, and for consolidation.

The incentives for consolidation were apparent. Figure 4 shows Clement Ward's estimated average slaughter cost function for beef plants with a capacity ranging up to 350 head per hour. Ward estimated comparable per-head reductions in per-head costs in the large fabricating plants. The plant killing and fabricating 330–40 head per hour across two shifts, a total of 5,440 per day, has per head costs of up to $20 below the costs of the plant killing and fabricating 100 head per hour, a large plant by the standards of the 1970s. The demand side problems portrayed the need to adjust in vivid terms and, simultaneously, turned theretofore sound operations like Wilson, Armour, and Swift Independent into takeover targets. It was often cheaper to buy the capacity than to build it, and IBP, Excel, and ConAgra emerged as the giants of the industry.

Review of Actions at Justice

The acquisition of Swift Independent by ConAgra in 1987 was apparently the last big decision at Justice with regard to consolidation in the beef sector. The Department's 1984 merger guidelines call for close scrutiny on any proposal that would push the post-merger HHI up by more than 100 points if between 1,000 and 1,800, or up by more than 50 points if the index was already above 1,800. The ConAgra-Swift Independent merger should have met one or both of these criteria but the proposed action was approved.



Source: The Helming Group. Research Department, Overland Park, Kansas.

Figure 3. Estimated packer margins (slaughter plus fabricating) by months, 1982–90

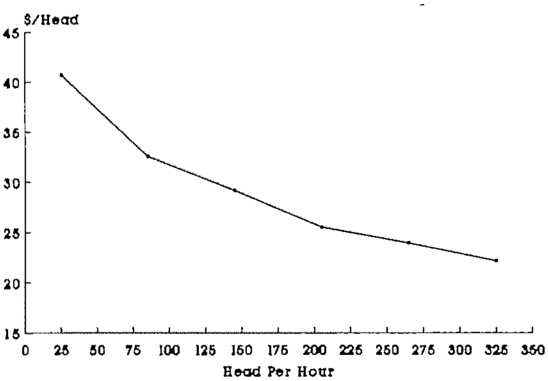


Figure 4. Estimated costs of cattle slaughter by size of operation

The courts had made clear in decisions in the 1970s that they were no longer willing to subscribe to a "big is bad" theme. But Justice may have moved to the other end of the continuum. Purcell concluded that the consolidation generated short-run benefits in that it brought efficiencies and saved part of the cattle industry by avoiding the need for still lower prices at the producer level. This conclusion is seen by Justice as confirming the correctness of the decisions in the ConAgra and Swift Independent case. The situation is more complex than that, however. The efficiency benefits can develop quickly and are amenable to possible documentation by looking at price spreads and proprietary packer-level margins. The farm-retail price spreads have not increased with overall price inflation across the past ten years and that has been immensely important to the beef sector. Connor (1989) concluded that profits in beefpacking have been near profits in other sectors of the food system, suggesting the reduction in farm-retail margins for beef was in fact the result of reduced costs at the packer level.

Generalizing the short-run positive impact of consolidation as a response to demand-side problems to a longer-run horizon would be inappropriate, however. It is important that the actions of Justice be considered in a broader context, and it then becomes clear how fragile the current situation could be.

Fed cattle slaughter has declined with the decline in the inventories. At the packer level, there is an estimated 20% to 30% excess capacity. The relatively small supplies of cattle when compared to existing slaughter capacity are providing a safety net of protection at the producer level against any market power levied by the larger packing firms. Excessive profits are not expected in the current environment. Instead, we would expect to see actions by packers designed to secure a supply of cattle.

The packers have taken action. With the consolidation have come changes in the way the industry operates. Kilmer discusses vertical integration as a way to achieve coordination of technically related states of activity when the external markets fail. In the presence of largely adversary relationships between cattle feeders and packers, the open-market price mechanism has never generated the highly stable flows of cattle that the packer would like to see, and we could argue the open market has failed. With the consolidation has come a number of mechanisms designed to achieve stability in cattle flows. They range from the business arrangement between IBP and Cactus, the world's largest cattle-feeding operation, to cattle being fed for packers either on contract or on a custom basis. There is no indication that the changes in the way the industry would operate were either anticipated or evaluated by Justice. But changes have come in the presence of large firms that dominate the buying side of the fed cattle markets, firms large enough to exert an influence on behavior in the cattle feeding sector.

The long-run implications of the consolidation continue to emerge and grow. They are reaching beyond the immediate impact on the sectors from which packers buy cattle and the sectors to which packers sell their products. Producers rely on publicly supported activities by the U.S. Department of Agriculture (USDA) for price and related information. In a consolidated industry, trade in carcass beef has all but disappeared. The USDA has dropped reporting of prices from the very thin carcass trade and has been forced to change and report a price index. Concerns that the cash fed cattle market is now so thin that it would be subject to manipulation prompted Kahl, Hudson, and Ward to recommend against moving to cash settlement for the live cattle futures contract.

The purpose here is not to provide an exhaustive list of all the issues that surround the consolidation. Rather, the purpose is one of suggesting that many important dimensions of the consolidation were not considered by Justice when the focus of attention was on the short-run increases in efficiency and on the arguments that ease of entry was an adequate safety net against the market power that was being created for three giant firms.

The Research Issues

The actions of Justice during the 1980s ran counter to the basic tenets of the SCP paradigm as a base for the enforcement of the antitrust statutes. There are some who now argue that the antitrust statutes are no longer appropriate and who call for legislative action. But the more informed observers appear to agree that it is not the statutes that need examination, it is the philosophy at Justice and the way the agency is looking at the issues that are the critically important dimensions. It is not the short-run efficiencies of a consolidated industry that are being questioned, it is the appearance of emphasis on

those short-run efficiencies to the exclusion of thoughtful deliberation on the long-run issues that is the concern.

The recent comments of Michael Porter, offered in another context, help to establish the perspective we might need to adopt. In discussing the actions of European nations to move toward greater economic unification, Porter is concerned that the orientation is wrong. He observes: "Their view of competition is a static one, in which eliminating inefficiencies and reaping economies of scale hold the key to success. . . . Greater dynamism, in the form of rapid technological progress, far outweighs the potential of static efficiencies to increase long-term prosperity" (*The Economist*, p. 17).

Is the consolidated beef industry of 1990 sufficiently competitive to generate the dynamism that Porter refers to and that leads to an industry that will perform in the best interest of society in the long run? If the answer is no, then the actions by Justice and the courts during the 1980s were wrong, and it is important that we move to a research methodology that helps generate a sound intelligence base to guide future decisions.

There is widespread empirical support for the SCP paradigm as a conceptual and methodological base. Weiss noted, after an extensive review, that the SCP paradigm is one of the most widely researched concepts in the history of economics. He concludes that the preponderance of the research efforts identify a causal flow from structure to conduct to performance. Connor (1989) discusses empirical findings relating structure to performance where the beef sector is concerned and references work of a number of market analysts dealing directly with the beef sector. A recent analysis of the meatpacking sector by Azzam and Pagoulatos, which employed data through 1982, concludes that market power was present on both the selling and buying sides, with the greater presence of power on the buying side. Schroeter looked at data for beefpacking through 1983 and found market power in both the selling and buying functions, but noted it was of small magnitude. Koontz, Hudson, and Garcia conducted a study of packer behavior in important cattle-feeding areas using a game-theoretic approach. The authors concluded that firms in the more concentrated areas would engage in "cooperative behavior" in the buying of cattle, with any deviations from that cooperative behavior coming during periods of exceptionally small supplies of slaughter cattle.

In 1980, Connor concluded there was no evidence of significant monopoly power in the meatpacking industry. But concentration levels at the time of the study were one-half of what they are in 1990, and almost nothing had been done to update research when the Justice made the important decisions in 1987. Connor concludes his recent search of the literature, conducted in 1989, with the overall conclusion that there is at most a modest (1.2% to 2.5%) price-depressing impact on fed cattle prices in the more highly concentrated packer buying areas. He notes, however, that much of the published literature covers time periods prior to the recent surge in concentration rates and continues in a qualitative assessment: "It is difficult to believe that the higher levels of concentration seen today . . . would not permit some price elevation" (Connor 1989, p. 90).

It is, therefore, not difficult to reconstruct the decision process at Justice. The literature supporting the SCP approach showed mixed results and was coming under attack from the Chicago School and contestable market advocates. In a political environment that was dedicated to deemphasizing the role of the federal establishment and in the presence of easily documented (by the merging firms) economies and efficiencies of large size, the arguments coming from the SCP school of thought were summarily dismissed by Justice. The arguments surrounding market definition and ease of entry were used to beat down any dissenting opinions as merger requests and proposed acquisitions were discussed.

The procedure for defining a market written into the Justice Department's 1984 merger guidelines helps to illuminate what occurred at Justice. Recognizing that the definition of "market" is very important in antitrust considerations, the guidelines pose a test based on a price increase. The guidelines read: Markets are delineated by postulating a "small but significant and nontransitory" price increase—generally an increase of 5 percent for one year—for each product of each merging firm at that firm's location and examining the likely response of buyers, sellers of other products, and sellers in other areas. If these competitive responses would cause the price increase to be unprofitable, then the area and group of products are expanded to include additional products and areas until the price increase would be profitable to impose (*Merger Guidelines*, p. 4).

It would appear that such a criterion would be

difficult to interpret, difficult to confirm empirically, and would be subject to virtually any conclusion. If there is predisposition to define the market broadly based on selected estimates of relatively high cross elasticities, the result is likely to be a conclusion that the increase in price would elicit a competitive response across many products and across a broad area.

The ease-of-entry argument is often devoid of conceptual or empirical rigor. To argue that firms could, or would, rush into boxed beef activity to earn a short-term profit and then escape with the investment intact involves heroic assumptions. An operation that is large enough to compete with the existing giant beefpackers would require a huge investment. The uncertainty of success in such an operation would dictate a discount for the uncertainty involved.

The incumbent and large beefpacking operations would be fierce competitors for their markets, and any firm considering entry would be acutely aware of that fact. The literature is full of arguments that advertising and product differentiation create formidable barriers to entry. Because the three large beefpackers are not heavily involved in branding fresh beef (Excel is the exception) there is a tendency to dismiss the possibility of barriers to entry, but that is a serious mistake. The firms may not differentiate their product at the consumer level, but they work aggressively to differentiate their product line and their services to their primary buyers, the retail chains. It would be extremely difficult for a plant killing cows, for example, to "slide" easily into boxed beef activity and combat the dominant control of the distribution, merchandising, and pricing networks of IBP, ConAgra, and Excel.[2] But there is clear implication in unpublished coverage of the deliberations during 1987 that Justice assumed such entry would be easy and would deter exploitation by existing firms.

It thus appears that the long-run implications of the consolidation in beef in the 1980s were all but ignored. With the efficiencies argument dominating attention, the pros and cons of the longer-run implications were not widely discussed. It is the long-run issues in consolidation that will set the agenda for the economist who conducts research in this area.

The long-run negatives will be those developments that come with the accumulation of market power in the hands of a few large firms. In spite of the safety net in the form of a tight supply of slaughter cattle, we are seeing the following:

(*a*) A cost-plus approach to pricing which insulates the packer and the equity investment in packing companies from the vagaries of the volatile livestock and meat markets. IBP has announced intent to sell boxes of beef on day $t + i$ at a derived price, calculated from live cattle prices on day t, plus a constant per head margin.

(*b*) A lack of progressiveness in terms of research and development. There is no evidence that the large packers are making the massive investment in market and product development needed to revitalize the beef sector.

(*c*) A move to captive supplies (contracted cattle, cattle fed for packers, etc.) in a consolidated industry that threatens to destroy the publicly visible price discovery base and to complicate efforts of public agencies to keep the producer informed.

There are also potentially positive long-run impacts of the consolidation. Among the possibilities are the following:

(*a*) The continued existence of economies of size. The dominant issue in the short-run evaluation of the mergers of the 1980s, those advantages will not disappear.

(*b*) The possible increase in efficiencies associated with vertical coordination via contractual and integrated activities. Modern kill lines and fabricating operation are designed to handle a specific quantity flow, and per unit costs increase rapidly at other volume levels. Contractual procurement and vertically integrated cattle-feeding operations allow the scheduling of cattle into the plants and help to insure the cost benefits of high-speed lines.

(*c*) The possibility of efficiencies in the form of increased responsiveness to economic stimuli. Weaver, Chattin, and Banerjee considered the speed of price response to changes in raw material prices or to changes at the consumer level. They found some evidence that concentrated industries are able to respond more quickly to price changes and other economic stimuli.

In an overall context, the methodological issues involve bringing increased conceptual rigor

[2] The four-firm concentration ratio for lamb slaughter is also very high, at 70 and above in recent years. In 1985, a new lamb-slaughtering operation was opened in northern Virginia by Rocco, a large poultry operation. The word in Washington and at Justice was that the Rocco effort was an indication that a new firm could come into a highly concentrated industry, and the effort was seen as verification of the ease of entry argument. Rocco operated for over two years, lost several million dollars in the process, and shut down in December of 1988. Company officials indicate they had major problems penetrating the existing distribution network in their targeted markets in the northeastern part of the United States.

to the existing empirical base in research on market structure. It is not sufficient to quantify a relationship between some measure of structure and profits if we do not know whether any increase in profits is caused by a reduction in costs or an increase in price. It is not enough to conclude that a highly concentrated industry is pricing the product above the so-called competitive price if a more nearly atomistic organization of the industry would preclude the reaping of important economies of size and economies of multiplant firms. We need less aggregation in the data in the econometric models that relate structure to some measure of performance, and we need to better understand the conduct or behavioral link in the SCP model. We need better measures of the costs and benefits of consolidation, more analysis of the benefits of changed operating procedures that come with consolidation, and investigation of the possibility of improved response to economic stimuli in a concentrated industry.

It is also important that we do analysis in both short-run and long-run contexts. It would appear that Justice and the courts gave far too much attention to the short-run cost and benefits of consolidation in the decisions of the 1980s and far too little to the possible problems associated with moves to cost-plus pricing, captive supplies of livestock, the lack of progressiveness in product and market development, and the private and public adjustments that must be made to the disappearance of a publicly visible price base for slaughter cattle.

At this point, it is overly optimistic to anticipate a methodology that sorts out the positives and the negatives and provides a measurement of the net impact of consolidation. But we can move in that direction. In looking at the beef industry and its continuing demand problems, a choice may be needed. We could, perhaps, have continued an industry structure with a four-firm concentration ratio of 40% and a 10% return on investment as a measure of profits with no firm possessing the financial capacity to do something about the market and product development needs. Alternatively, we could have the current structure with a concentration ratio of 80% and a return on equity of perhaps 20% and the financial prowess necessary to do something about the demand problems. I would applaud the actions of Justice to allow the consolidation if there were ways of insuring the product and market development work would be done and if there were means of insuring that the now-large and presumably more efficient firms would be forthcoming in reporting prices and in working with the other sectors of the industry. But those conditions are not being met. Perhaps research is needed to document the pros and the cons and to suggest legislative action to protect the interest of the public. If profit margins and expenditures on research and development are treated as strictly proprietary, then we may need to consider the required reporting of expenditures on research and development. If the huge firms show an increased propensity to internalize transactions such that no prices are involved or prices are not publicly available, then the need for required reporting must be discussed so that the many small producers are not denied access to market information.

It would be counterproductive to discuss reversing the massive consolidation in beef. Much of what happened was in response to a major economic shock from the demand side. But developments in the beef sector provide an excellent case study to sort out the pros and cons of consolidation. If we can put together the research thrusts needed to measure the implications of consolidation, then future deliberations by Justice and by the courts dealing with other parts of the food systems can be on a broader and more nearly balanced base of information.

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Empirical Challenges in Analyzing Market Performance in the U.S. Food System

John M. Connor

When viewed over the last century or more, the changes in the market structure of the U.S. beef subsector resemble nothing so much as a roller coaster.

Beef slaughtering and processing were dispersed, on-farm activities until well after the Civil War. During the 1880s, meatpacking was among the first food industries to become significantly monopolized. The appearance of a radically new distribution technology, the mechanically refrigerated rail car, and new corporate forms of ownership provided the stimuli for both horizontal mergers and extensive vertical integration. The "Beef Trust" controlled about 85% of U.S. sales of dressed beef in the 1880s (Yeager);[1] this is consistent with the Big Four meatpackers (all red meat species) control of 71% of U.S. federally inspected slaughter in 1920 (Nicholls, p. 333).

The machinations of the Beef Trust, believed to have depressed western cattle prices and elevated retail beef prices in eastern cities, were in no small measure responsible for the Sherman Antitrust Act, which became law in July 1890. Later, by order of President Wilson, the Beef Trust became the target of the first investigation of the newly established Federal Trade Commission. As a result of the FTC 1919 report, the Big Five meatpackers were compelled in 1920 to sign a perpetual consent decree with the Department of Justice. The decree required the Big Five to cease their market-pooling arrangements, to forego further consolidation in meatpacking, and to sell their stockyards, railroad equipment, refrigerated warehouses, retail meat stores, and non-meat food-processing plants. The Packers Consent Decree is often cited as one of the first examples of successful antitrust policy (Aduddell and Cain, Connor et al.) The peak of control of cattle slaughter by the Big Five was around 1918 (fig. 1). Concentration glided slowly downward for the next sixty years, reaching its nadir in the 1970s, when the top four accounted for a more 20% of national cattle slaughter (Connor, p. 80).[2] Except for a slight rise in lamb slaughter concentration until the mid-1930s, all other red meat slaughtering also declined to historical lows between 1967 and 1977. Part of the success of the decree may lie in the monitoring and licensing powers of the Packers and Stockyards Administration, formed in 1921.

It is a strange sort of roller coaster that can climb higher on its second loop than at its start. Yet, beefpacking appears to be defying the gravity-like laws of market-structure change.[3] Abetted by the most permissive period of federal antitrust enforcement since the early 1930s, beefpacker concentration has risen to new heights. From 1977 to 1987, the top four companies' share of U.S. steer/heifer slaughter climbed from 29% to 67% (Connor).[4] This astounding 131% increase in concentration is more than twice as rapid as any other historical decennial increase in other U.S. food and beverage industries. Furthermore, much as the case a century before, the

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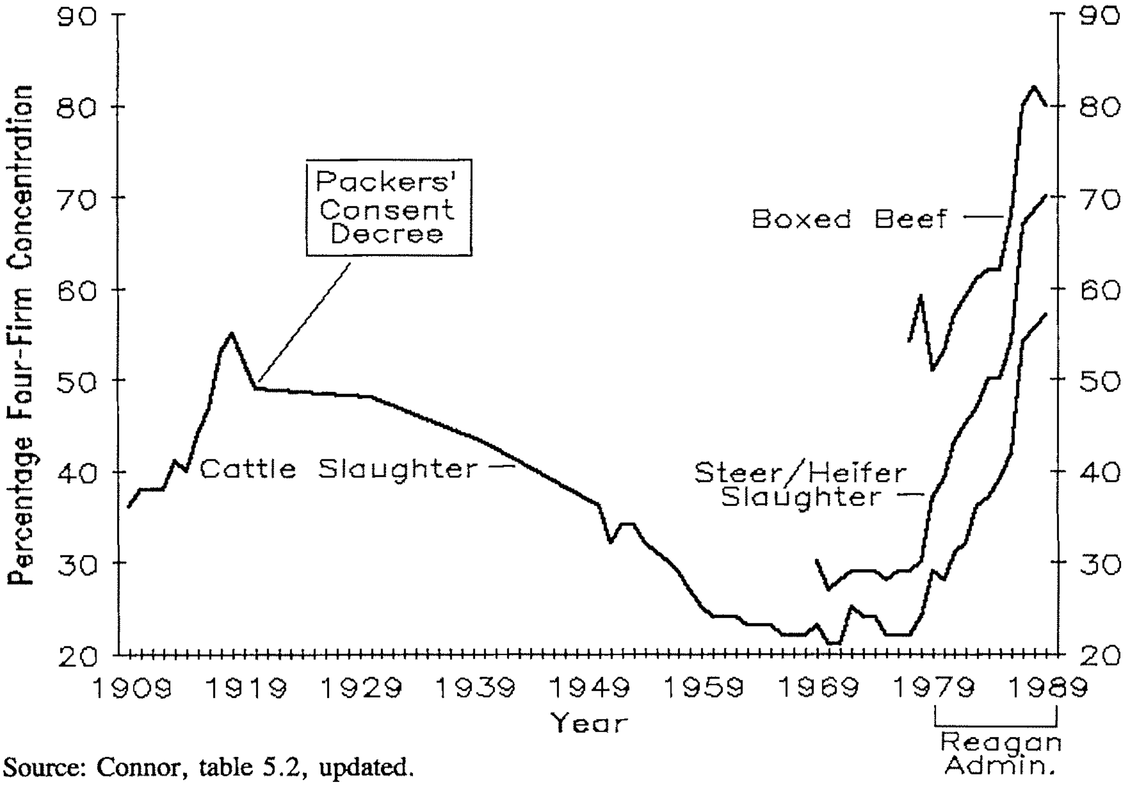
[1] The Beef Trust was not, as its name implies, a single company linked by common stock ownership. Rather, it was a market-pooling arrangement effected through a jointly owned subsidiary company. The Big Five Meatpackers from 1890 were Armour, Cudahy, Morris, Swift, and Wilson. In 1923, Armour acquired Morris; thus the Beef Trust became the Big Four. These same four firms remained the leading meatpackers until at least 1959.

[2] Four-firm national sales concentration in meatpacking (SIC 2011), which is computed on a somewhat different basis by the Census Bureau from slaughter concentration, also reached its lowest level (19%) in 1977.

[3] More precisely, the 1947–77 historical pattern of concentration change in food manufacturing has been one of convergence toward the mean (Connor et al.). Since the early 1980s, beefpacker concentration has diverged from the food industries' mean.

[4] Slaughter concentration data were available separately for steer/heifer and cow/bull types beginning in 1969. During the same period, cow/bull slaughter concentration rose 82%, and for all cattle rose 145%. Boxed beef concentration data begin in 1977 when the top four accounted for 54% of volume.



Source: Connor, table 5.2, updated.

Figure 1. Four-firm U.S. beefpacker concentration, 1909–89

increase in business consolidation was spurred by a major technological innovation in manufacturing. First commercialized in the early 1960s, the new "boxed beef" technology became the dominant form by 1980, largely supplanting carcass beef by the late 1980s. During this period, packer margins narrowed and economies of plant scale enlarged considerably. I have argued (Connor) that from its inception boxed beef was sufficiently distinct as to warrant classification as a separate market at the processing and distribution stages of the beef subsector. Boxed beefpacking is even more concentrated than beefpacking generally: about 40 firms operate boxed beef plants today, compared to more than 1,000 other beefpackers, with the top four handling 80% of production volume. Packer concentration among other red meat species has also risen since the 1970s, albeit more slowly. Many observers believe the hog slaughtering may be the next industry poised for rapid concentration increases.

In light of these historical developments, what can industrial organization analyses tell us about economic performance in the beef subsector, particularly since the mid-1970s? A recurring theme of this paper is that there has been marked progress in the measurement of market structure-performance relationships. Yet, by the early 1980s, gaps in this body of knowledge were apparent, and the deficiencies were further exposed by developments affecting the field of industrial organization generally. Thus, I believe that a number of exciting challenges await empirical researchers studying the livestock subsectors in the 1990s, challenges that arise from the evolving vertical linkages, rapid structural changes, and increasing internationalization of some subsector stages.

In the next section, I shall sketch with a broad brush the principal areas of progress in market-structure research in the food industries, drawing illustration mainly from the beef subsector. In the final section, I will discuss a number of problems with the present state of knowledge and suggest four promising areas for empirical research.

What We Have Learned

In the beginning was Bain (1959). His textbook defined the field of industrial organization. Not only did Bain specify the structure-conduct-per-

formance paradigm such that it encompassed the burgeoning body of oligopoly theories that had been accumulating since the early 1930s, but also he set the stage for statistical analyses of cross-industry date that were to become the dominant model of empirical testing. Until Bain's seminal 1951 article, hopes for validating the structure-conduct-performance paradigm had rested on cross-industry comparisons of in-depth industry case studies (Bain 1972). However, because of limitations inherent in the historical method, the case studies did not prove generalizable and were largely abandoned by the end of the 1950s.

Profit Margins

Bain's empirical work in the 1950s was primitive by today's standards.[5] It employed aggregated, multiyear-accounting profit rates of selected industries for its peformance index; four-firm national concentration ratios and judgmental classification of ease of market entry were the only two determinants of profitability considered. Progress in statistical cross-industry studies was rapid in the 1960s and 1970s. The major improvements and refinements can be well illustrated by the twenty or so published studies of manufactured foods surveyed in Connor et al. (pp. 280–97). Improved data permitted more objective measurement of proxies for product differentiation and barriers to entry. Market share information allowed researchers to match the profits of diversified firms more precisely to the market environments that were partially responsible for generating excess profits. Moreover, models were able to take into account such nonstructural sources of variation in profitability as product quality differences, market growth, capital intensity, firm size, and sales diversification. A number of studies were able to avoid the diversification problem entirely by utilizing establishment-level or profit-center data on price-cost margins, which are rather good representations of the Lerner index of market power. Greater attention was paid to whether results were sensitive to the business cycle or to definitions of submarkets with distinct conduct patterns, including the vertical relationships, alternative marketing channels (private label and foodservice, for example), and international dimensions (trade and direct investment). Finally, the robustness of results was checked against alternative econometric formulations; generalized-least-squares and simultaneous-equations techniques were tried.

Despite the impressive variety of approaches taken by a large number of independent researchers, Connor et al. concluded that "the profit-structure relationships estimated for the food manufacturing industries show a remarkable consistency across the empirical studies reviewed . . ." (p. 289).

In a nutshell, all of the studies with decent data and appropriate analytical tools had shown that market concentration and product differentiation were positively associated with profitability, whereas economies of scale and other technical barriers to entry were unrelated to profits. Alternative data sources, time periods, econometric models, and nonstructural factors did not affect the statisitical significance of the principal relationships. Moreover, depending on the degree of aggregation, the market structure-performance models were able to explain as much as 80% of interindustry variability in margins, which is more than satisfactory for cross-sectional studies.

Selling Prices

Although the finding that concentration and product differentiation determined industry and firm profits seemed indisputable as an empirical regularity, already by the early 1980s nettlesome doubts had begun to creep in concerning the interpretation of extant profit-structure studies. Researchers conceded that claims of statistical causality (in a Grangerian sense) could not be made (Connor et al., pp. 285–86). Hence, concentration (as a proxy for the recognition of mutual dependence among sellers) and product differentition (resuting from the nature of demand or to barriers to entry created by it) could only be deemed "determinants," not causes. However, it was noted that time-series analyses had shown secular persistence for the manufacturing sector as a whole (Connor et al.).

A more serious criticism concerning interpretation of results focused on the concentration variable. As concentration rises, so do the market shares of leading firms. From the point of view of consumer welfare, the higher profits associated with greater concentration could mean one of two things. First, under conditions of nondecreasing unit costs of production (as in Industry 1 of fig. 2), unit selling prices would rise

[5] Of course, profit or price-cost margins address only one of several dimensions of market performance, viz., allocative efficiency. Connor et al. (pp. 297–321) also addressed other dimensions of performance (income redistribution, technological progressiveness, technical efficiency, and so forth), but the points I wish to make are likely to be unaffected by focusing on allocative efficiency alone.

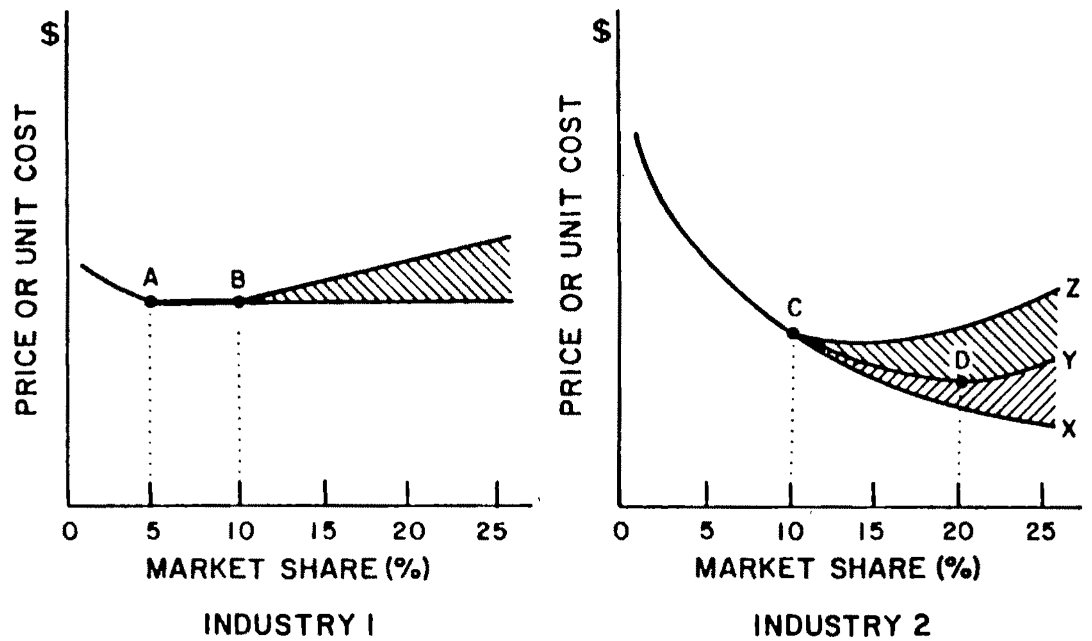


Figure 2. Hypothetical cost and price curves in two industries with different economies of scale

in tandem with increasing a profit rate. Indeed, in the presence of X-inefficiency (often alleged to be correlated with profitability) consumer prices would rise proportionately higher than profits. Second, when economies of scale are present (as in curve CX for Industry 2), consumer welfare can actually increase even though excess profits are being generated by the high market share. In other words, firms may be profitable simply because they are innovative (an early entrant), lucky (market share the result of random growth processes), or more efficient. In these cases, high profits are socially condoned because they are generated by lower costs and not necessarily because of higher prices (that is, prices are lower at D than at C).

The reasoning behind the second theoretical possibility is unassailable. But what empirical evidence can be brought to bear that would decide between the two cases?

One riposte is that some food-manufacturing studies utilizing detailed firm profit data have included both market shares and concentration as explanatory variables. Presumably the "efficiency effect" should be picked up by variations in market share, whereas the "collusive effect" will be captured by the industry-wide concentration variable. If both variables are positive and significant, market power is present. While the evidence from the rest of manufacturing is mixed on this point, food-manufacturing studies consistently display the market power result (Connor et al.).

A more direct approach is to test the relationships between market structure and selling prices directly (Weiss). This is most easily accomplished in the case of intra-industry prices across geographically segmented markets, such as airfares, retail grocery prices, gasoline, or bank interest rates. Here, the relationship of concentration to price is uniformly positive, which tends to dismiss the efficiency hypothesis as empirically groundless.

Because so many of the markets for processed foods are national in scope, testing structure-price relationships is considerably more challenging. However, one such study did overcome the data and modeling constraints (Wills and Mueller). Price variation was obtained by developing an index of prices of various brands of the same products keyed to the price of the leading brand. Not surprisingly, process food prices were found to be positively determined by brand market share and advertising intensity, especially when the latter was electronic. The result held for both retail and for wholesale prices.

Having this sort of corroborating evidence on food prices available, Connor et al. were so bold as to display with some confidence the estimated effects of noncompetitive market struc-

tures in the early 1970s on 1975 manufacturers' prices (p. 291). The results for the meatpacking industry indicated a consumer overcharge of practically zero; the meat processing industries, on the other hand, had a predicted overcharge of a little more than 1%. Taking into account other performance dimensions, both industries were judged to have quite low consumer overcharges (pp. 328–29).

There is contradictory evidence on whether beef selling prices are as competitive today as they were in the 1970s. The notable price rivalry of the Big Three suggests that they are. On the other hand, the countervailing power of meat buyers has probably fallen. In the 1950s to 1970s, beefpackers' sales were less concentrated than the principal buyers of carcass beef. The main buyers are the divisional (regional) buyers for retail grocery chains and specialized beef wholesalers. In 1958, the average U.S. metropolitan area had 48% of grocery sales concentrated in the hands of the four largest companies (Connor, p. 82). In rural areas, concentration is even higher. Among specialty beef wholesalers, city concentration was about 30%. I know of no way of blending these concentration figures, but total beef distributor concentration at the metropolitan level was somewhat above the 22% to 30% national seller concentration of the packers. Distributor concentration today has increased since the 1950–70 period, but not nearly as fast nor as far as packer concentration. Four-firm retailer concentration is now above 60% in the average U.S. city, and wholesaler mergers have likely driven meat wholesaler concentration to at least 40%. Despite these substantial increases on the distributors' side, since then packer concentration has raced far ahead. Moreover, in the case of boxed beef, retail chain purchases seem to have become more centralized, and national sales concentration of grocery chains is much lower than average metropolitan concentration. I take this to be weak evidence of a shift in the balance of power between packers and distributors in favor of the former.

Buying Prices

The original structure-performance approach had estimated the impact of market structures on overall margins. But firms with market power can in principle exercise that power either by raising selling prices of products (as just discussed) or lowering the procurement prices of inputs. Which of the two routes powerful firms will choose to emphasize will depend largely on the degree of countervailing power they perceive downstream as sellers or upstream as buyers.[6]

Several systematic studies are available supporting the exercise of market power on the buying side—monopsony power. Packers buy mainly from independent feedlots, some of which act as agents for beef producers. Whereas regionalized buying by distributors tends to raise concentration in ways unfavorable to packers, the geographically limited (100- to 200-mile radius) procurement zones for live cattle tends to favor the packers. Views differ on the appropriate number of cattle-buying markets, but in the principal cattle-raising areas west of the Mississippi River the number of proposed markets ranges from ten to twenty. A painstaking study of cattle concentration in the western United States placed four-buyer concentration at an average of less than 50% in 1971. By 1987, the average exceeded 90% (cited in Connor, p. 81). Feedlot concentration in the same areas is far lower.

There are several careful statistical, cross-sectional (or pooled time-series/cross-sectional) studies of the relationship of buyer concentration and cattle prices. The studies employ a variety of time periods from 1971 to 1980, geographic market definitions, and control variables. In my judgment, the concentration-price relationship that is estimated by the three most ambitious studies is remarkably similar (Menkhaus et al., Quail et al., Ward). Allowing for numerous nonstructural factors, each study found that fed-cattle prices were from 1.2% to 2.5% lower in the most concentrated procurement zones relative to the least concentrated. Similar analyses of slaughter lambs and hogs also found the expected inverse relationship between buyer concentration and livestock prices.[7]

What We Do Not Know

Perhaps, like any new technology that has come close to being perfected (by the standards and objectives established at the beginning), the in-

[6] Of course, this oversimplifies. Firms may decide to try both or neither.

[7] One of the few areas of disagreement is the plant-closing studies. While they show that prices fall (relative to some reference point) when plants close (increase in buyer concentration), they disagree on the length of time for which prices are lowered.

novators of the statistical cross-industry method of analysis were destined to become disenchanted by their creation. While self-criticism was certainly important, an additional stimulus to the reappraisal of structure-performance analysis was the increasingly influential criticism of the Chicago school of economic analysis (Posner). The well-known Arlie House conference reported in Goldschmid, Mann, and Weston may be regarded as the opening shot in the oftimes rancorous debate that followed.

In an influential review of interindustry studies of the market structure-performance relationships, Schmalensee harshly asserts that inter-industry studies are now out of fashion. The main reasons he gives are that inappropriate data and methods have been used, "conventional," i.e., Bainsian, interpretations are wrongheaded, and "formal models" of conduct are absent. Schmalensee also faults traditional interindustry studies for failing to yield consistent estimates of structural parameters and are useful only to provide stylized facts to guide theory construction.

Perhaps a more useful view is the Hegelian one suggested by Martin. The thesis is the fundamentally empirical structure-performance studies in the Bainsian mode. The antithesis is the essentially microeconomical-theoretical position of the Chicago school, which views the model of perfect competition as the actual long-run equilibrium of markets unobstructed by the dead hand of government.[8] The synthesis is what has been dubiously dubbed the "New Industrial Economics," a convergence in views that recognizes the importance of explicit theoretical models as underpinnings for empirical tests while at the same time allows the data to produce results that diverge from perfect competition (rather than treating it as the maintained hypothesis or untested assumption of the research). Much of the best empirical research of the future will probably try to satisfy the requirements of both camps, the mainstream (Bainsian) and the Chicago.[9] At this juncture, the "New IO" empirical studies strike most mainstream researchers as woefully lacking in the richness of detail that was attained by the best IO studies of the 1970s.

Despite these caveats, there are four areas of research I would point to as especially promising ones.

The Specification of Conduct

The IO empirical literature of the 1960s made rather vague appeals to a priori reasoning in formulating testable models of structure and performance. It is true that nearly all oligopoly models predict equilibrium prices that are above competitive (but below pure monopoly) levels. But the standards of the literature are rising in the sense that a behavioral model is expected to be formally derived from a theoretical model of, say, profit maximization incorporating an explicit mode of pricing conduct. Connor and Peterson is an example of a cross-industry test based on such a formally derived model. In this instance, the derivation justified the inclusion of the Hirshman-Herfindahl index of concentration and the conventional industry advertising-to-sales ratio; however, the model also required data on the elasticity of demand with respect to own price, an explanatory factor largely ignored in previous structure-performance studies. It is perhaps comforting to note that parameter estimates, where comparable, were similar to previous studies. Another published study of the food industries, though not directed at estimating static allocative efficiency, is the article by Gisser, which adopted two explicit pricing behaviors.

The major disadvantage to introducing explicit conduct modes is the necessity of choosing one when many are possible. When one of several options is adopted as an operating assumption, suspicion may naturally arise about the sensitivity of the results to the assumption. Of course, testing alternative paradigms is standard operating procedure for social scientists, but it could diminish the chances that the results will be of practical policy relevance. Perhaps realistic market experiments with experienced players playing for large stakes would offer insights into pricing behaviors (Plott).

Time-Series Approaches

A major alternative to the cross-industry analysis that has emerged since the early 1980s may be termed the intra-industry time-series approach. Data from only one industry or group of related industries are used to determine whether firms exhibit behavior consistent with compe-

[8] Alternatively, all private monopoly power is temporary. "Chicago concedes that monopoly is possible but contends that its presence is much more alleged than confirmed, and receives reports of its appearance with considerable skepticism. When alleged monopolies are genuine, they are usually transitory . . ." (Reder, p. 12).

[9] Policy research is, however, another matter. The two schools are so far apart here that a synthesis seems highly improbable.

tition or consistent with market power. These intra-industry studies require an econometric model, but profits or price-cost margins are treated as nonobservable. Often, but not necessarily, parameters are described in terms of firms' conjectural variations, their expectations about the reactions of rival firms to a change in quantity of output.

More than a dozen such studies have been published covering a range of industries, including meat, all food processing, roasting coffee, and tobacco (see Bresnahan). In general, the results of the new technique support the traditional structure-performance approaches. Industries with relatively high concentration levels have substantial power over price, as indicated by the implicit price-cost margins. The food and tobacco studies found price-cost margins in excess of 50%; the coffee industry displayed mostly price-taking behavior, except for the largest firms. The meatpacking study by Schroeter also finds evidence of noncompetitive behavior.

This type of empirical analysis, while admirable in its theoretical rigor, has many limitations. The very simple model formulations imposed by the requirement of mathematical tractability leave little scope for assessing the sources of market power, only its longevity. Moreover, many of the interesting, policy-relevant questions in IO cannot yet be addressed. The impact of product differentiation, the role of entry conditions, and the detection of strategic entry deterrence are examples (Bresnahan).

Long-Run Equilibrium

Both the cross-industry and intra-industry approaches assume that the industry(ies) being observed is(are) in long-run equilibrium. As we know, if deviations from the long-run equilibrium are uncorrelated with the independent variables, then a cross-sectional econometric model will yield consistent estimates of long-run parameters. Unfortunately, many of the instrumental variables employed in cross-sectional studies are not truly exogenous; there are, for example, many feedback effects from performance to structure. Multiple equation models cannot resolve this problem, although recursive systems and time-series panel data might well yield consistent estimates.

There can be little doubt that in the 1980s the beef subsector was in disequilibrium. The effects of radical technological change in production are still radiating throughout the industry. The pressures to keep huge, new plants running at full capacity may well have caused cattle prices to be higher for the first few years, until other beefpackers closed or sought new market niches in order to survive. After fifteen to twenty years of running at full capacity, even boxed beef processors began to experience substantial underutilization of capacity in the late 1980s. One possible implication, so far undocumented, is that the excess capacity was allowed to develop to discourage new entry, thereby making pricing discretion by established firms greater than before.

International Dimensions

Traditional structure-performance analyses have treated international trade and foreign direct investment as exogenous influences. Trade, most commonly modeled as an import/supply ratio, is interpreted as a measure of the ease of foreign market entry; alternatively, the export/sales ratio is sometimes used to indicate the extent to which a firm or industry is able to exploit economies of scale that may be constrained by a national or regional market. I have argued that the disciplining impact of beef imports is negligible, except perhaps in the case of lean beef purchased by fast-food hamburger chains (Connor). The export side is much more complex. The United States is a net exporter of beef products, most of which are hides, other nonedible byproducts, and variety meats. Exports of grain-fed boxed beef are increasing, but they are influenced by regulatory and structural restrictions in the importing country as well as by the exports of the joint products mentioned. If leading beefpackers export more proportionately than smaller firms, then national concentration ratios are overstated. It is not known whether exporting is an integral part of overall selling strategies or simply seen as a "vent for surplus."

In general, foreign direct investment has had a greater impact on overseas sales by U.S. food manufacturers than has export trade; similarly, foreign food companies now sell far more in the United States through their affiliates than through imports (Connor). The trend toward inward investment has accelerated since the mid-1970s. Foreign investment in ranches, feedlots, and beefpacking was negligible as of 1987, but recently a number of smaller West Coast packers have been acquired by Japanese interests purportedly to serve the Japanese market. So far,

foreign investment is too small to have had an impact on competition in the domestic beef market. Even if investments were to become large, it is only through adopting different conduct that the competitive impact of foreign ownership becomes of interest. There is precious little research on even those food industries with high levels of foreign investment as to how industry performance has been affected.

Conclusions

The Bainsian (SCP) analysis of food industries has yielded results that are impressively rich in detail and remarkably consistent estimates of structural parameters. Faulted for the rigor of its theoretical underpinnings, the cross-industry method of analysis is being supplemented by the New Industrial Organization. Four areas of research in the food industries would appear to offer the greatest promise for satisfying the dictates of both schools: (*a*) models with explicit modes of firm conduct, (*b*) time-series or conjectural-variations approaches, (*c*) studies of entry conditions, and (*d*) models that permit differential conduct by foreign-owned firms.

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Measuring Market Power in Food-Processing Industries: Discussion

John R. Schroeter

Historical developments in the evolution of industrial structure in beefpacking, particularly the rapid increase in concentration over the past ten years, provide the point of departure fot both of the papers in this session. Purcell notes that the wave of consolidation of the decade of the 1980s built upon already substantial concentration in the industry. The fact that it nonetheless was allowed to proceed reflects the political and philosophical attitudes that prevailed in the courts and the Department of Justice during the period. Proconsolidation arguments demonstrating the clearly documented potential for economies of scale flourished in a regulatory climate characterized by a general aversion to government interference in the private sector. Anticonsolidation arguments, raising the specter of abuses of market power, were easily deflected by rebuttals that sought to minimize the degree of concentration, through broad market definitions, or the danger of concentration, through endorsement of the monopoly-deterring powers of potential entry.

Purcell argues that the regulatory authorities simply dismissed traditional concerns founded upon an assumed causal linkage between concentrated industrial structure and antisocial economic performance. Connor's paper reviews what we know about this structure-performance link in the beef sector and in food-processing industries in general. Most of the accumulated evidence on profitability-concentration and price-concentration correlations comes from cross-industry studies in the spirit of Bain; that is, studies employing the traditional "structure-conduct-performance paradigm" (SCPP). A clear consensus emerges from these: The studies generally demonstrate a positive relationship between food industry concentration, on the one hand, and both profit and selling price, on the other. In the beefpacking industry specifically, there is also agreement among several studies on the existence of a negative relationship between packer concentration and price of slaughter cattle in regional procurement markets. In recent years, however, industrial organization economists have become skeptical of the ability of the Bainsian cross-industry approach to detect the presence of market power. Connor notes this conversion and points out that the religion it has established, the "new empirical industrial organization" (NEIO), has both merits and shortcomings. I would like to devote the bulk of my discussion to an elaboration of these, particularly as they manifest themselves in the analysis of packer oligopsony power in cattle procurement markets.

The SCPP approach is widely familiar. In the unvarnished extreme, it involves the use of cross-sectional data to estimate an ad hoc reduced-form equation expressing a performance measure (price-cost margin, rate of return on equity, price) in terms of various structural measures (concentration, conditions of entry, product differentiation) and possibly additional "exogenous" variables inserted as controls for other important cross-industry differences (market growth rates, advertising intensities).[1] In the NEIO approach, on the other hand, time-series data from a single industry is used to estimate a system of structural equations that obtain from a clearly specified, firm-level optimization problem. Indices of conduct and performance are treated as parameters to be estimated rather than observables.[2] Bresnahan attributes the development of the NEIO to three beliefs that undermine the validity of the SCPP methodology:

(*a*) Industries have important idiosyncratic characteristics that cannot be summarized adequately by a few exogenous variables.

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[1] Several cross-industry studies model the determination of more than one endogenous variable using a simultaneous equations approach. Schmalensee argues that even these models are unlikely to provide consistent estimates of structural parameters.

[2] In many of these studies, the device of a conjectural variation is used to parameterize conduct and/or performance. Examples of applications to food processing include Lopez, Roberts, and Schroeter.

(*b*) Meaningful performance indices (Lerner's index, for example) cannot be directly measured using available accounting data.

(*c*) Estimation of ad hoc reduced-form relationships between structure and performance is not very informative.

Connor notes that the three most ambitious SCPP studies of packer market power in cattle markets (Ward; Menkhaus, St. Clair, and Ahmaddaud; Quail et al.) reach general agreement on the existence of modest oligopsony distortions in fed-cattle prices. How do these three studies, all similar in technique, fare in light of Bresnahan's three criticisms of the SCPP? To my mind, they are relatively safe from attack on the first two counts. They use data sets consisting of observations corresponding to geographically and/or temporally separated versions of essentially the same market. Consequently, the degree of heterogeneity among observations in these studies is far less than in Bain's pioneering study or any of its descendants using census data on diverse manufacturing industries. The similarity of the markets also suggests that cross-observation differences in packers' marginal net revenue product for cattle might be, if not insignificant, at least adequately explained in terms of a few exogenous variables. Under these circumstances, the price paid for cattle is an acceptable index of the degree of oligopsony power. Thus, dependent variable measurement is not a problem because price is easily observed and, at least in these markets, scrupulously recorded.

This brings us to Bresnahan's third point, the alleged superiority of the theory-based structural models of the NEIO approach to the ad hoc reduced-form models of the SCPP approach. The underpinnings of the econometric models of modern NEIO studies certainly are much fancier than the informal theory supporting the regression equations in SCPP studies, but does this additional formality contribute anything beyond an outlet for mathematical pedantry?

We estimate empirical models because we seek answers to certain key questions; in the present context, questions of how market performance compares to the competitive benchmark. With ad hoc models, the only method for validating the empirical results is to check whether the implied answers to these key questions are "reasonable"; or, to put it somewhat less delicately, to check whether they conform with the analyst's prejudices. This method of model confirmation builds in an obvious bias toward validation of the conventional wisdom: Models are "good" if they confirm our beliefs. In contrast, NEIO empirical models are structural in nature. Each parameter has an economic interpretation which, in light of theory, often suggests checks on model validity that are independent of the questions of interest.[3] In other words, NEIO theoretical models imply overidentifying restrictions that provide an objective basis for model evaluation.

NEIO theoretical formulations also contribute identifying restrictions that enhance the credibility of the models' assessments of market performance. Conventional approaches usually fail to impose certain relevant theoretical restrictions. These omissions cast doubt on the models' ability to identify correctly market power effects.

For example, consider the fed-cattle market studies of Ward; Menkhaus, St. Clair, and Ahmaddaud; and Quail et al. Figure 1 illustrates the basic model underlying these studies. Regional supply and derived demand, or marginal net revenue product, determine a competitive price P_c. If packers exercise oligopsony power, actual price will be lower than P_c. The regression equations include supply and demand variables, that affect P_c, as well as a linear term in concentration that is supposed to capture the magnitude of the oligopsony distortion, the gap between P_c and the actual price. But, in reality, the oligopsony distortion also depends on supply elasticity in a systematic way. To see this,

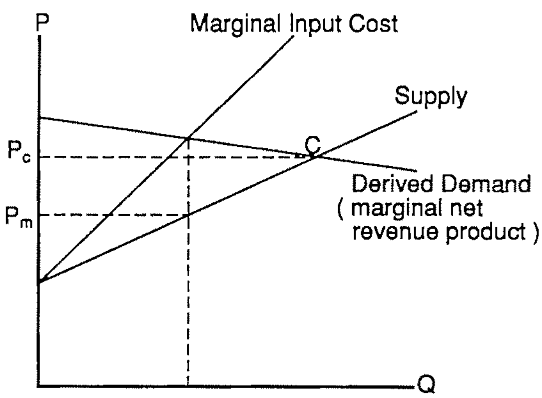

Figure 1. Basic model for fed-cattle studies

[3] Estimated supply or demand elasticities can be compared to results from independent studies. Cost function parameter estimates can be checked for consistency with the properties of monotonicity and concavity. In Schroeter and Azzam (Selected Paper, this issue), the theory implies the testable overidentifying restriction that an expression for a farm/wholesale margin contains no constant term.

imagine two initially identical, regional markets with concentrations that are equal and sufficiently high so as to enable the areas' packers to effect the pure monopsony outcome, P_m. Now imagine that the exogenous supply determinants in one region cooperate in performing the following thought experiment: The supply curve rotates clockwise about the competitive equilibrium point, C. The oligopsony price distortion will now be smaller in the market with more elastic supply even though the competitive price level, concentration, and conduct (pure monopsony) remain the same in both markets. The point is that theory imposes restrictions on market performance; in this case, restrictions relating supply elasticity to the magnitude of the oligopsony price distortion. If these are not built into the model, there is nothing to insure that the concentration term captures the whole of the price distortion and nothing else. It is conceivable, for example, that the negative relationship that the authors found between packer concentration and cattle price reflects a spurious correlation with omitted variables that shift supply or demand and therefore affect P_c, not $P_c - P_m$.

So the principal advantages of the NEIO approach to the measurement of market power stem from the fact that it is built on a foundation of a clearly specified optimization problem. As Connor points out, its major disadvantage is that the analyst must first specify that optimization problem in terms of one particular objective function to the exclusion of others. What is the appropriate objective function for modeling firm conduct in oligopoly settings? In one sense, "profit maximization" is the indisputable answer since most viable "alternatives" to profit maximization can be reconciled with it, given an appropriately lengthy decision horizon or an appropriately broad set of choice variables. Of course, this observation merely restates the question in different terms. As a practical matter, most NEIO studies to date model industry equilibria over time as solutions of a series of independent, static profit-maximization problems. While this may be a reasonable approximation in many cases, it usually is inappropriate in the case of food-processing industries. Food-processing firms face agricultural supply curves which, because of inherent production lags, incorporate important dynamic elements. In utilizing market power to move industry equilibrium along a market input supply curve this period, food-processing firms alter the menu of price/quantity options that will be available to them next period. A rational firm, anticipating these future impacts of today's actions, will incorporate them in its decision-making calculus: The relevant objective function is intertemporal in nature. Recent work by Karp and Perloff has taken an important step toward showing us how to measure market power in dynamic oligopoly settings. I hope that future work will follow this initiative.

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Structural Change in Food Systems: Discussion

Larry Martin

I like the two papers by Purcell and Connor, although they both leave me with a sense of frustration. This is due to the fact that, while we are mathematically more sophisticated, the conflict about the relationship between market structure and market performance that raged when I was in graduate school twenty years ago has clearly not yet been resolved.

The two authors took different approaches. Connor provided a useful overview of the literature during the past decade, with some emphasis on results for meat packing. Purcell's paper concentrates more on the actual events and outcomes in the beef sector. Perhaps it is because of their different approaches, but I felt there were two (fairly minor) conflicts in the two papers. The conflicts will be discussed below, followed by a set of largely eclectic points about the issues of concentration and performance in the beef packing industry.

Conflict One

Purcell says structural change in beef processing was largely the result of the decline in demand for beef. Connor attributes it to the introduction of boxing technology.

They are probably both right, but in my view Purcell is more right. The decline in demand has been extraordinary, and its implications for economic survival have been no less so. We should all applaud Purcell's rather lonely campaign to get our profession and the beef industry to clearly understand this phenomenon and to untangle its implications. His work in *CHOICES* and other places has clearly defined the demand problem and has pointed out our profession's delinquency in understanding and helping. The fact that the econometric literature he cites has finally begun to include enough time-series observations to find statistical evidence of the glaringly self-evident merely illustrates, once again, how good we are at arriving too late with too little to be of relevance. We need to expose more graduate students from major land grant institutions to Purcell's graphical analysis and a few right brain analytic techniques.

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Conflict Two

Purcell says consolidation in the packing industry has resulted in increased efficiency. Connor seems to reject this mainly by omission, but also by citing Weiss. Once again I find Purcell's straightforward analysis to be quite compelling. It fits my priors about what has happened in this industry as the "Big Three" have driven it in terms of technology, management, and capacity utilization. Even from the perspective of the Canadian industry, the need to compete with the American firms at some level has put tremendous pressure on Canadian firms to improve their efficiency and productivity.

Some Additional Points

Below, a number of points are addressed about the beef-processing industry from my perspective in Canada.

First, both papers, Purcell's especially, were a little unclear at some points concerning whether they were addressing slaughter, fabricating, or value adding when they were discussing concentration ratios. The (roughly) 80% four-firm concentration ratio could be misleading if, as in Canada, it is different for the three levels in the United States. My sense is that concentration ratios are much lower in the value-adding portion of the industry. If this is correct, and the packers and fabricators are attempting to penetrate and hold this growing market, then one would expect the competitive implications to be quite different than if the value-adding segment were highly concentrated. This is one of those com-

plicating factors that makes the structure-conduct-performance paradigm so oversimplified.

A second point involves the long-term implications of international trade for the concentration issue. I think more emphasis needs to be placed on international trade than was done in the papers. There are at least three components of my concern. First, the tarrification of the Japanese market in 1991 will bring substantial change to this industry, as will the emergence of a strong market in Korea. Papers by Hayes and by Kerr, Hobbs, and Gilles at other sessions of these meetings give a clear indication of the nature of the Japanese market and some notions about its implications for the United States and Canada. Japanese demand is highly specific and highly quality conscious. In order to penetrate that market and to compete with other countries, products will require a longer shelf life than we are now able to provide, and they must be processed with a slow and costly technique. It is a situation that does not lend itself to the massive economies of scale of the processes currently used by major U.S. packers. Who will fill this niche, and what implications will the emergence of such companies have on competition in the North American market? We may even find that North Americans will become quality conscious.

The second issue with respect to international trade involves the Canada-U.S. trade agreement and a potential trade agreement with Mexico. Once one starts using a relevant market that goes beyond the boundaries of the United States, concentration ratios get lower and more competition is added. Substantial competition is occurring in the northern plains and southern prairies for cattle during these times of short kills. I do not believe the results are consistent with the expectations that devotees of the structure-conduct-performance paradigm would assign to a three-firm concentration ratio of 80%.

The third issue having to do with international trade is the apparent conflict between domestic concerns by U.S. economists regarding concentration ratios and their unconcern with U.S. trade law. If there is increasing concern about improving the competitive outcome in the United States, then one would think that U.S. agricultural economists would be concerned about insuring as much competition as possible. Despite this, U.S. agricultural economists do not seem to be concerned that the United States obtained a waiver of its GATT obligations on dairy in 1955 but then takes steps to stop other countries from using exactly the same trade restrictions for dairy products as the United States uses. They seem to be not concerned about the fact that the United States has imposed highly questionable countervailing duty actions on Canadian pork imports, threaten to do so on beef, and have been successful in convincing European interests to voluntarily restrict exports to very low levels into the U.S. market.

Finally, while the United States has agreed to harmonization of meat inspection procedures with Canada under the Canada-U.S. trade agreement and is, apparently, about to agree on harmonization in the GATT, it is clear that we are far from the point at which these agreements are followed by the United States. Harmonization should, in theory, make it easier for countries to compete in each other's markets. Therefore, the corollary is that failure to harmonize makes it more difficult for others to compete in your market. Failure to harmonize when one pays homage to harmonization should not be a matter that U.S. agricultural economists stand idly by and witness.

Purcell briefly made a point about the quality of data from the U.S. industry. I am increasingly wary of using U.S. price data because of the thinness of markets. In Canada, we have kept much of our price-discovering mechanisms in the open, and at least some of the data are reliable. This is in part because we have mandatory marketing legislation in the case of pork, and because a number of producers and packers had the good sense to use either electronic or sealed bid transaction techniques in the case of beef. In the United States, you are coming dangerously close to the point where the analysis conducted for antitrust action will have to be based on the data of the accused. In my experience, the accused may have a vested interest in insuring that the data are appropriate for their cause.

A fifth point is a seeming inconsistency between the concern about market power and Purcell's concern with a lack of product development. Purcell makes it sound as if there is a vast untapped market for beef that is not being exploited because companies have failed to do the required product and packing development. This is a bias with which I identify. However, if this market opportunity is available and the three major packers have such market power, then one wonders why they are not pursuing it and turning it to their advantage. Either they know something we do not or we have misinterpreted what they are doing.

My final point is with the narrowness of the structure-conduct-performance paradigm. Lis-

tening to the discussion in this session, I have heard several measures of performance discussed. They include cost, profit, product development, research and development, and market differentiation. Taking two of Purcell's points that I have discussed above illustrates a dilemma. We can combine his notion that packing plants have become more efficient with his concern about lack of product development in the face of declining demand. The bottom line for this combination is that the industry has become increasingly efficient at producing a product that consumers do not want. My concern is that market performance is an extremely complicated and multifaceted concept. To try to measure it by using a four-firm concentration ratio and one or two other variables in an equation that explains internal rates of return seems to me to be absolutely useless in measuring the utility and public welfare produced by an industry. To continue along this route when the business school literature is uncovering and elucidating such concepts as total quality and the extremely complex and multifaceted nature of becoming competitive, as pointed out by people like Peters and Porter, is to miss the boat rather strikingly. We simply have to move to a more complete, if mathematically less appealing, model of performance if we are to use antitrust notions to improve public welfare.

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Agricultural Changes in Eastern Europe at the Beginning of the 1990s

Csaba Csáki

Rapid political and economic changes are occurring in Eastern Europe. The political fermentation grown out of economic difficulties has resulted in a sudden change in all countries of this region. The decrease of economic output, backwardness in world development, and the failure of economic and political reform attempts have radically countered the grounds of the post-Stalin economic and political structure. The changes in most countries have overstepped the traditional reform boundaries and suggest a total rejection of the socialist-communist system.

When studying the current Eastern European agricultural problems, we should recognize that the agricultural changes underway represent a much more profound process than the reforms in past years. The formation of a new agricultural structure built on private ownership, real cooperation, and a market economy has begun. This process is still in the initial phase; the details are often taking shape in heated discussions. Thus, I can only summarize the most important general and country-specific developments, trends, possibilities, and dilemmas.

The Current Position of Eastern European Agriculture

This study will survey the problems of Bulgaria, Hungary, the GDR, Poland, Romania, and Czechoslovakia, the six "small countries" out of the European CMEA countries.[1] These six countries comprise about 2.5% of the world's population (112.8 million) and they have little influence, except for some exceptional cases, on the world market of agricultural products. In these countries, industry now is a dominant branch of the national economy, although the importance and consequences of the agrarian sector are still stronger than in the majority of the developed countries. Agriculture's proportion of net national production is between 8% and 20%. The lowest is the GDR and Czechoslovakia and the highest is in Hungary and Romania. The conditions are similar considering the proportion of agricultural population (9% in the GDR, 10.6% in Czechoslovakia, 13.9% in Hungary, 14% in Bulgaria, and 24% each in Poland and Romania). The agricultural population is tending to decrease, but the decrease of agricultural workers slowed considerably in the second half of the 1980s.

All the countries are found in a temperate continental climate zone. In the northern countries the climate is more humid, cooler, and soil quality is less. But, the conditions of agriculture are above average in Romania, Hungary, and Bulgaria.

Across all six countries, 57.8 million hectares of agricultural area are available for production. The agricultural areas have decreased in some of the countries over the long term, although the decrease of tillable areas has slowed in more recent times. The proportions of agricultural cultivation areas range from 53.3% in Czechoslovakia to 70.5% in Hungary.

Agricultural Growth—Production Outcomes

The agriculture of the six countries developed quickly in the early 1970s, but the process then slowed. At the beginning of this period, the total annual rate of production growth was about 3% to 4%. By the beginning of the 1980s, the growth rate was in the 1.5% to 2.5% range and

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[1] At the end of the 1980s, numerous studies and analyses were written on the position of the Eastern European agriculture: e.g., Wadekin, Csáki (1988, 1989), and a series of USDA and FAO studies.

differed significantly among countries. By the end of the 1980s, the total growth rate declined to 1% to 1.5%. Nonetheless, the agricultural growth of more than 2% a year, which is characteristic of the entire region in the long run, is going to be a significant result.

The large fluctuation of production growth in each country is striking. In the countries concerned, the decrease of agricultural production growth paralleled the decrease of general economic and industrial development. In fact, the relative decline in nonagricultural activity exceeded the agricultural decline, thus bringing agricultural and nonagricultural activity closer together.

In all the countries concerned, the main agropolitical objective was to increase self-sufficiency and especially to develop grain production. In past years, the grain-producing areas remained essentially constant, falling in the 54% to 58% range of sown crop land. The planted area of major crops is shown in table 1. Even though improved yields were increasing production in most countries, imports were still needed to satisfy the increasing demands. In general, the efforts to increase grain production cannot be considered successful. Although the balance of grain trade of these six countries is still negative, only Hungary exports a considerable amount of grain, about 2 million tons a year.

The contradictory development of past years is shown by the average crop yields in table 2. Relatively poor crop yields and high annual fluctuations in output characterize all of the countries. The output levels reached by the Western European countries are approached only by Hungary, the GDR, and Czechoslovakia.

Since the early 1970s, the six countries have made continual efforts to develop animal husbandry (table 3). The numbers of animals have increased, and professional breeding technologies were introduced. The production of animal products outgrew the increase of grain and fodder production in each country. The development was quicker in the first half of the 1980s and in some of the countries, especially Hungary and Bulgaria, the growth of animal husbandry and meat production decreased by the end of the 1980s.

Within meat production, poultry and pork production in particular were developing. In poultry production five out of the six countries increased production by more than 10% per year in the last decade. Beef production was relatively stable, while mutton production was less than average. Egg production was developing rapidly, but milk production was developing only moderately; here Hungary is an exception in that its milk production was one of its most rapidly developing areas.

As we can see, many factors explain the constraints on agricultural growth following the dynamic developments of the 1970s. The problems of the total economy are significant. In addition, a distinction occurred in the late 1970s between the development of plant cultivation and animal husbandry.

Animal husbandry and the development of breeding technologies could not keep pace with the development of plant cultivation. Animal husbandry was not economic, and the efficiency of feedstuff consumption fell behind the levels achieved in well-developed countries.

Table 4 shows that tractors used in agricultural production have grown considerably in all the countries, although the number of tractors has decreased in the GDR and Hungary as a result of structural changes. The development has clearly shifted towards larger, more efficient machines. In past years, the change of the machine fleet has slowed considerably, which is harmful to the agricultural production capacity, especially in Poland and Romania.

Table 1. Planting Area of Major Crops (1,000 hectares)

Countries	Wheat	Maize	Barley	Potatoes	Sunflower Seed
Bulgaria	1,138	563	360	40	240
Czechoslovakia	1,239	190	751	170	27
Germany D. R.	777		895	431	
Hungary	1,242	1,124	282	74	359
Poland	2,195	51	1,175	1,858	
Romania	2,600	3,100	680	325	460
Western Europe	18,568	6,429	13,483	1,877	2,324
World	225,951	129,664	71,962	18,070	15,376

Source: FAO, Agrostat. 1990, Rome.

Table 2. Average Yields, 1989 (metric tons per hectare)

Countries	Wheat	Maize	Barley	Potatoes	Sunflower Seed
Bulgaria	4.7	4.3	4.4	13.5	1.9
Czechoslovakia	5.1	5.3	4.7	18.6	2.3
Germany D. R.	4.5		5.2	21.3	
Hungary	5.3	6.2	4.7	17.6	2.0
Poland	3.9	4.8	3.3	18.5	
Romania	2.3	3.8	2.6	22.2	2.4
Western Europe	4.8	5.8	3.9	25.1	1.7
World	2.4	3.6	2.3	15.3	1.4

Source: FAO, Agrostat. 1990, Rome.

Table 3. Production of Major Livestock Products in 1989 and as a Percentage of 1970

Country	Total Meat	Beef and Veal	Pig Meat	Cow Milk	Total Meat	Beef and Veal	Pig Meat	Cow Milk
	(1,000 mt)				(%)			
Bulgaria	814	121	413	2126	206	155	281	170
Czechoslovakia	1635	409	937	7101	157	130	166	148
GDR	1987	420	1368	9300	156	122	168	131
Hungary	1588	120	1010	2812	170	101	177	167
Poland	2801	660	1753	15700	141	130	136	105
Romania	1628	235	920	4350	181	109	197	158

Source: FAO Agrostat. 1990, Rome.

Table 4. Tractors Used in Agricultural Production

Years	Bulgaria	Czechoslovakia	Germany D. R.	Hungary	Poland	Romania
1970	55.3	136.0	148.9	67.9	224.5	107.3
1980	62.0	136.7	144.5	55.5	619.4	146.6
1985	55.2	137.0	158.0	55.3	924.6	184.4
1988	53.7	141.2	167.5	52.8	1101.3	183.0
1988 in percentage of 1970	97.1	103.8	112.5	77.8	490.6	170.5

Source: FAO, Agrostat. 1990, Rome.

The increase of chemical fertilizer consumption, measured by effective substance, leveled off in the second half of the 1980s. Stagnation and recession are characteristic (see table 5). Above all, the quick rise of chemical fertilizer prices curtailed the increase of chemical fertilizer consumption.

The Development of Food Consumption

In the first half of the 1980s the standard of living of people in most of the countries was still improving. But this increase stopped in the second half of the decade, and a recession in the standard of living can be observed in almost every country. In most of the countries, calorie consumption per person fell with a range of 3,300 to 3,500 calories a day.

The differences between the countries are substantial. Considering the well-developed countries, cereal consumption per person in Eastern Europe is relatively high. Within vegetable consumption, cabbages and tomatoes are dominant. Generally speaking, fruit consumption is low, especially tropical fruits.

The food markets hide interesting contradictions in the region. In some of the countries, where a market economy has already begun, the change in prices of the past period resulted in the absolute recession of food consumption. Although exact data are not yet available, in the first half of 1990 food consumption is estimated to have declined in Poland by 30% and in Hungary by at least 15%. In these countries a market situation is increasingly dictating the demand-supply conditions of foodstuffs. The food market is still characterized by excess demand in

Table 5. The Quantity of Chemical Fertilizers per Hectare of Ploughland and Plantation

Years	Bulgaria	Hungary	GDR	Poland	Romania	Czechoslovakia
1970	159	150	319	162	67	230
1975	166	276	370	236	114	305
1980	205	262	325	244	113	334
1987	183	260	337	244	125	303
1988	218	268	367	224	133	311
1988/1970	137.1	178.7	115.0	138.3	198.5	135.2

Source: FAO, Agrostat. 1990, Rome.

Romania and Bulgaria, where consumption is at a much lower level. In both countries, deficiencies of supply and the governments' export preference policies are the primary reasons the inhabitants are still missing vital foodstuffs.

Eastern Europe and International Food Trade

The changes of the agrarian world's trade in the last decade adversely affected the Eastern European countries. In 1988, 2.8% of the world's agricultural imports were directed into these countries and they provided 2.5% of global exports. On the whole, the agro-export structure of these countries has not accommodated to the new world market situation of the 1980s. Agrarian protectionism affected most of the countries unfavorably.[2]

In years past, the level of grain self-sufficiency was increasing, as mentioned above, but the balance is still negative. Meat self-sufficiency is higher than 100% in the entire region. The region is traditionally independent in vegetable oils, and some of the countries are, or soon will be, ready for export. The six countries are largely self-supplying in fresh vegetables; if market conditions are provided, they can easily offer important exports. The degree of self-sufficiency in fresh fruit supply is in the 90% to 96% range, although the demand for tropical fruit is largely unsatisfied. The balance of agrarian trade in the region is negative on the whole. The total negative balance is $1 billion to $1.5 billion a year, which covers a self-sufficiency level of about 98% (table 6).

In agrarian trade the six countries can be classified into two groups: The GDR, Czechoslovakia, and Poland are in an import position. For GDR and Czechoslovakia, the amount of net import is particularly important. Besides significant imports, Poland has considerable exports, too; its net agricultural imports fell to about a quarter of the amount during the past ten years. Hungary, Romania, and Bulgaria are exporting countries. Hungary's food production export surplus is especially important; in 1988 more than one-third of the total European CMEA agro-export came from Hungary.

The differences in structure of exports and imports are substantial among the European CMEA countries. Cereals, industrial crops, meat products, fruits and vegetables, tropical fruits and tropical agricultural products, and above all coffee are dominant among imports. For exports, if Hungary's grain export is disregarded, meat and meat products, vegetable oils, and fresh and processed vegetables and fruits prevail.

The turnover of agricultural products differs among each country's economy and international trade relations. The proportion of agricultural products is the highest, about 25%, in Hungarian exports; second is Bulgaria at about 18%. In Czechoslovakia, agricultural products have a share of only 6% to 7% of exports. On the import side, the GDR is in first place, and Romania is in last place; in Romania, agriculture comprises less than 10% of imports. Disregarding absolute rates, the foreign exchange outlay of agricultural trade and export returns is very important for the balance of payments in all of the countries. This statement is particularly valid for the countries with relatively large amounts of debt, where the hard currency balance of agricultural trade in both positive and negative directions can be of significant importance.

In the agrarian trade of the Eastern European countries, Western European relations are most important among the well-developed countries.

[2] Agrarian protectionism has an extremely disadvantageous influence on the Eastern European agro-exporting countries which were not able to support export. It was not accidental that Hungary joined the Cairns Group. Of course, the importing countries here also enjoy the advantages of relatively low world market prices. See this topic also in Csáki (1989).

Table 6. Foreign Agricultural Trade of the CMEA Countries (in millions of U.S. dollars)

Years	Bulgaria	Czechoslovakia	Germany D. R.	Hungary	Poland	Romania
Imports						
1981–83	755	1,766	2,186	856	2,085	1,054
1985	1,010	1,722	1,691	721	1,281	515
1988	1,211	2,233	2,187	857	1,783	529
Exports						
1981–83	1,397	592	509	2,178	698	1,059
1985	1,125	568	409	1,847	901	863
1988	1,783	718	540	2,148	1,291	764
Balance						
1981–83	632	−1,174	−1,677	1,322	−1,387	5
1985	115	−1,154	−1,282	1,126	−380	348
1988	572	−1,515	−1,647	1,291	−492	235

Source: FAO, Agrostat. 1990, Rome.

Western Europe is the most significant demand market for the quality food products of the Eastern European countries, although the share of the six countries from total Western European imports is extremely low, 2.5% to 2.7%.[3] In years past, agricultural exports from Western Europe to the six countries exceeded imports. The GDR, Czechoslovakia, and Poland are the leading buyers. The main sources of grain sales are the well-developed industrial countries outside Europe, although these exports are not significant; sales by Romania, Hungary, and Poland in North American markets (primarily meat products and highly processed food stuffs) are examples.

Particular attention must be paid to agricultural trade within the European CMEA region. Traditionally, the smaller European countries, above all Hungary and Bulgaria, and in lesser amounts Romania and Poland, exported food products to the Soviet Union according to long-run agreements. The Soviet Union paid for the food stuffs in energy and raw materials.

In the 1980s, about half of the Hungarian agricultural exports and more than two-thirds of Bulgarian food products found their market in the Soviet Union. This network of relations is deteriorating. In the Soviet Union, the energy-transportation facilities are becoming more limited. In addition, Soviet balance of payments is not in a favorable position. On the Soviet side, these developments have led to the accumulation of a relatively significant negative balance of trade against several Eastern European countries by the end of the 1980s. Of the countries concerned, first Hungary reacted with food export restrictions. They are not able to grant the credit needed by the Soviet Union, similar to the credit on food imports from the well-developed countries. It is not accidental that, in the last nine months (e.g., simultaneously with the decline of the Eastern European food export directed into the Soviet Union) food exports of the European economic community into the Soviet Union grew by almost 300% (AgriEurope 1990).

[3] Senior Nello has studied the agrarian trade relations between the EEC and the Eastern European countries in detail.

Reform Attempts in Eastern European Agriculture

In the 1950s and 1960s a socialist reorganization of agriculture was carried out in all six countries. It was equivalent to the collectivization of an agriculture of mainly smallholders according to the Soviet models. The state estates and agricultural cooperatives became dominant in all the countries except Poland by the mid-1960s (table 7). The organization of socialist large-scale farms was accompanied by the development of a planned economy and by a centrally prescribed and planned agricultural production. A significant recession accompanied the reorganization in all the countries except Hungary. It was obvious even in the middle of the 1960s that the administrative central direction was constraining agricultural production growth. Other signs of dissatisfaction with the system also appeared. As a result, in the second half of the 1960s, the first period of reform of the socialist agricultural systems occurred.

The main objective of reform was to change the character of direction. Two alternatives were

Table 7. Use of Agricultural Land by Various Farm Types 1988

	Total Agricultural Area	State Farms	Cooperative Farms	Private Use
	(1,000 ha)	(%)		
Bulgaria	6,162	89.9[a]		10.1
Czechoslovakia	6,765	30.3	63.6	6.1
GDR	6,182	7.7	82.5	9.8
Hungary	6,497	14.9	70.9	14.2
Poland	18,742	18.5	3.6	77.9
Romania	15,094	90.5[a]		9.5

Source: *CMEA Yearbrook 1989*. Moscow, 1990.
[a] State and cooperative farms together.

considered. One of the reform groups saw security only in the perfection of planning methods; the other group supported decentralization, the increase of companies' independence, and the increased use of economic incentives. Finally, in most countries reforms which weakened central direction and fostered decentralization were adopted. However, the practical implementation of these reforms was problematic. Publication of reform ideas did not assure implementation; in several countries, parts of the planned arrangements were introduced experimentally. In this first wave of reforms, only in Hungary did a significant change finally occur; here the indirect direction system introduced in agriculture outperformed the solutions applied in industry. The new economic mechanism resulted in a relatively rapid development of Hungarian agriculture (Csizmadia and Székely).

Disregarding the Hungarian reforms, the agricultural directions systems considered new at the beginning of the 1970s did not achieve the expected results; they did not accelerate the agricultural development process. Moreover, in 1972–73, some retirement occurred in the decentralization process of almost every country because of political pressures. However, in the second half of the 1970s, a new situation was developing. The changes in the world's economy and the oil crisis increased tensions about the economic problems in the region. It became clear, particularly in some countries, that an agriculture organized and directed by earlier methods could not keep up with the demands of consumers. Thus, a second wave of reforms was initiated which basically sought to more thoroughly advance the objectives of the first reform; but it was without much success.

The third period of agricultural reforms in Eastern Europe began in 1985–86 and lasted through 1989. The general economic crisis of the region and its backward development can be considered the antecedents of this wave of reforms; moreover, in some of the countries high indebtedness occurred as well.[4]

The failure of past reforms and the sharpening political tensions ripened the demand for radical changes. In this period the central objectives of agricultural reforms were as follows: to improve efficiency and quality of production, to move toward a price policy reflecting the real costs of production, to increase the role of financial incentives, to provide greater decision-making freedom for firms, and to widen the possibilities of private agricultural production.

The third wave of reforms did not equally affect the countries because of differences in patterns of political changes. In the GDR and Romania, the decision-making freedom of companies and decentralization were quite limited. In Czechoslovakia, to a lesser degree, the independence of companies, economic incentives, price reforms, the role of financial instruments, and private production support were all increased considerably and reinforced. In Hungary, where these arrangements had begun earlier, the food industry and foreign trade were partially decentralized. The idea of transforming the weakest cooperatives into a loose cooperation of private producers also arose. However, in the latter four countries these changes coincided with the final days of planned economy, and they could not produce perceptible results.

In the second half of 1989, the political turn sweeping Eastern Europe meant the beginning of a new agricultural era as well. The sequence of attempts to reform the socialist agricultural systems was over. Efforts to formulate a new agricultural structure replaced the reform ambitions. This change is clearly evident today only in the GDR, Hungary, Poland, and Czechoslovakia (Wos, Wadekin) where, together with the introduction of the real multiparty system, the power of the communist party also came to an end.[5] Similar progress is occurring in Romania and Bulgaria, although the positions of Communist parties here are rather stable. Thus, the political and agricultural perspectives of the future are still doubtful. The character of change in the Soviet Union is similar to that of the Eastern European countries, but here, too, the official language is still using the term "reform."

[4] This period is analyzed in detail by Csáki (1988).

[5] Wos studies Polish reforms; Wadekin analyzes the latest happenings in detail in the agriculture of the GDR, Czechoslovakia, and Bulgaria.

Change in Eastern European Agriculture

The main direction of the transformation of Eastern European agriculture, similar to the general economic and political changes, can be easily identified. In every country the objective is to develop an agricultural structure based on a market economy with private initiatives and private ownership. The principal characteristics of the new system and the critical points of the future can only be outlined today. However, the most important tasks are the following:

(*a*) An unambiguous requirement is to create marketable landed property.

(*b*) The farming structure, which is presently large scale, must be adjusted toward small and medium-sized agricultural private ventures and a system of cooperatives of various types existing together with the state or communal farms.

(*c*) Develop a governmental attitude which fosters these ventures, supports the emerging private entities and attends to the transformation of the cooperative sector.

(*d*) An agricultural policy which serves the efficiency of agricultural production by means utilized in the market-oriented, well-developed countries and enforces the traditional objectives of income parity of agricultural producers is needed.

(*e*) A real agricultural market is needed which guarantees fair competition.

(*f*) A basic, fundamental change in the role of government.

(*g*) The agricultural policy under transformation must consider as an objective the environmental protection of nature.

The Landed Property, Reprivatization

One of the biggest dilemmas in Eastern Europe involves landed property. It is clear that the creation of marketable landed property is unavoidable. The adaptation of farming structure to the market conditions is also needed.

Numerous alternatives are possible. First, it is helpful to survey the landed property relationships in Eastern Europe. Except for the Soviet Union, in the countries concerned, land was not completely nationalized after the war. In addition to state property, cooperative landed property also arose, and private landed property existed in various forms as well. Over the years, proprietary rights came to be only formal, over and above the proprietary rights of land in private handling. Together with the abolition of the land market, land lost its character as a valuable asset. In Eastern Europe, land values cannot be found in the registry of agricultural implements. Land costs are not calculated in various agricultural accounts either.

It is not accidental that one of the most debated political and economic questions involves landed property. All over Eastern Europe a host of opinions currently exist; the most important are the following:

(*a*) To keep the present forms of property ownership and to allow land control through leasing.

(*b*) To give the land to those individuals who wish to be agricultural producers.

(*c*) On the basis of proprietary rights before collectivization, to give land to all those who aspire to work in agriculture, together with financial compensation for earlier proprietors who did not take an active part in agricultural production.

(*d*) To reestablish with no restrictions the landed property relationships existing prior to collectivization.

The land property decision is unknown at present, but the process will probably differ among the countries. In Czechoslovakia, Hungary, and the GDR, the discussion about such land issues is currently underway (Wadekin, Csáki and Varga); however, in Bulgaria and Romania, the question has not yet been formally put on the agenda, although the land demand of private producers is noticeable here as well.

Future Farming Structure

The agricultural structure of the countries was formed by the collectivization process of the postwar period. The objectives of collectivization were similar in each country, but the methods of execution and resulting structures differ. In the GDR, Czechoslovakia, Bulgaria, and Romania, the socialist reorganization of agriculture was consistent with the Soviet model. In these countries the typical form of agricultural enterprise was the state or cooperative large-scale farm of several thousand hectares (table 8). In Bulgaria the agri-industrial complexes emerged as special entities that fused the state and cooperative forms. In the middle 1980s in Bulgaria, 150 large complexes were working and spanning most agricultural regions. A particular characteristic of Eastern Germany is the separation of plant cultivation and animal husbandry. In Czechoslovakia and Romania, the co-

Table 8. Main Indicators of State and Cooperative Farms in 1988

	State Farms		Cooperative Farms	
	Number	Average Agricultural Area	Number	Average Agricultural Area
Bulgaria				
Czechoslovakia	238	6,042	1,657	2,597
GDR	465	995	4,549	1,121
Hungary	133	6,015	1,397	3,299
Poland	1,266	2,601	2,207	310
Romania[a]	419		4,363	

Source: *CMEA Yearbook, 1989*. Moscow, 1990.
[a] In 1985.

operatives and state farms have been largely independent until now.

Collectivization has followed its own course in Hungary, where cooperatives have always been relatively independent. In terms of household farming plots, private agricultural production still exists. Poland was able to preserve the predominance of private farms, but the government long impeded the natural progress of private ownership in agriculture. The classical private farms could survive the reorganization of agriculture only in low numbers. Only in Hungary was household and complementary farming often supported by the government. The production structure of private agriculture was also unique. Private growers dealt primarily with animal husbandry and gardening; grain production and plant cultivation were almost exclusively concentrated in the large farms. The rate of private production is the lowest, about 10%, in the GDR and, apart from Poland, highest in Hungary, where one-third of the production came from the private sector in recent years. In Czechoslovakia the contribution of private production to total agricultural production is 10% to 12%, about 25% in Bulgaria.

What will be the future of cooperatives and estates in Eastern Europe? In their present form, these farms are not suitable for a market economy. They are too large, not profit centered, and are lacking in entrepreneurship. It is probable, based on the results of tests in the GDR and Hungary, that much of the cooperative membership does not want completely independent production (Wadekin, Csáki and Varga). So it is probable that part of the cooperatives will be abolished, and new forms of cooperation will open the way to individual farming along with the present cooperatives. Private production will gain strength, but it is impeded by numerous factors: lack of capital, undeveloped credit systems for villages, high interest rates, the lack of buying systems for farm products, lack of technical implements used in private farming, and managerial deficiencies, especially in finance and economics.

The reprivatization processes for the state-owned estates in other parts of the economy must be considered. Agricultural enterprises in state and public ownership which operate with a joint stock structure are found in the countries as well. Their role will be important in seed grain and breeding stock supply and in consultation services. Some of them will function as diversified agribusinesses, and they may be instruments for attracting foreign capital to support agricultural production.

The above processes will fundamentally change the enterprise structure of agriculture in Eastern Europe. It is questionable whether these changes can occur without a temporary decrease of agricultural production, given the political tensions in the region. The peasant people's love for work and perseverance suggest optimism, as the historical examples also show. Nonetheless, during the transition period the temporary disturbances of agricultural production can be avoided only by well-considered government policy.

Agricultural Market Creation

The new agroeconomic structure presumes that a real market system of food economy can be developed. This market system must support production, the domestic food market, and international markets, too. Organizational, institutional, legal, ethical, and economic regulatory issues are involved as well.

A fundamental requirement to create a market is to make the processes of food production and sale and the production and supply of factors of production a unified system joined by economic relationships. In all the countries food processing is a bottleneck.

Considering the formation of agricultural markets, the improvement of technical conditions cannot be neglected either. Nowadays, the wholesale trade of agricultural products, delivery to consumers, and retail trade are all very primitive in the countries involved. The proper facilities, organizations, and technical knowledge all are missing. The building up of a fi-

nancial system joined to the agricultural sector and the creation of a provincial network of banks and credit institutions are also needed.

The governments are trying to make up for this backwardness, but conditions for true competition have not yet been reached, and the lack of these conditions impedes the gains from price liberalization as well.

The State's New Responsibility

The removal of the bureaucratic state management system has already started, but this work will take time to complete. The degree of change differs in each country. The system of planned targets has been abolished, but several bureaucratic and attitudinal barriers still exist. The pivotal question of the state and production relationships involves price and assistance policy. The characteristic features of the classical Eastern European agricultural price system are as follows: The majority of the producer and consumer prices were pegged by the government; the agricultural producer prices were fixed on the basis of domestic production costs, mainly those of large farms. Thus, most prices were significantly different from both the norm and as proportions of the world market export prices; the earlier economic policy fixed the producer prices of food products at reduced levels.

Rapid changes are occurring in the policy areas as well. State regulation of consumer and producer prices is weakening. The transformation is strongest in Poland and Hungary. In Poland in 1989 and in Hungary in January of 1990, producer and consumer prices of foodstuffs were almost completely liberalized, along with the reduction of consumer price assistance.[6] (Currently in Hungary only wheat for meal and milk have official prices among the agricultural products).

All the countries apply some kind of agricultural export subsidies. The effects of these subsidies cannot be distinguished in the data. It is unlikely that such subsidies will be abolished until the effects of protectionism are substantially reduced in international agricultural markets.

The global budgetary system of relationships of agriculture is being transformed. A complex set of taxes and subsidies can be found in all of the countries. In general, the burdens of economic difficulties are being increasingly shifted to agriculture by the governments. As a result, the balance of the budgetary relationships of agriculture has become negative in most countries in recent years.

Political Transformation of Rural Areas

In all the countries the classical party state has been abolished. In addition, political reforms in rural provinces are rapidly occurring.

In the GDR, Czechoslovakia, and Poland peasant parties existed in an earlier time as well, but their operation was only formal and was strongly subordinated to the party in power. These peasant parties have now become independent political forces. Moreover, in Hungary, Bulgaria, and Romania the peasant-related parties are being revived.

The political force of the revived peasant parties differs among the various countries. A particularly strong and vigorous policy characterizes the peasants' party of Poland and the smallholders' party of Hungary, which are both members of the ruling government coalition. In Hungary the political party favoring the agricultural cooperative sector also was founded. And, in Bulgaria and Romania the peasants' parties in opposition are significant powers.

Transformation is characteristic of the agricultural representative organs as well. The representative system of agricultural producers and rural people is also being formed. In all the countries new unions, chambers, and associations are marking the beginning of a fundamentally new political era.

International Agricultural Relationships

As already cited above, the CMEA and the Soviet-oriented, traditional, agricultural international system of relationships of the Eastern European countries has been dismantled. The future of the GDR is clear. In the immediate future, the country will become an integrated part of the agricultural structure of the common market and will also become a part of the unified Germany and thus a member of the EEC. Similarly, agriculturally import-oriented Czechoslovakia is leaning toward the western countries and gradually opening its agricultural markets.

[6] Today in Hungary, for example, among agricultural products, only wheat for meal and milk have official prices. Related to this, among food products, only the price of white bread, crescents, rolls, and milk of 2.8% fat content were officially fixed.

The reinforcement of western orientation is likely for Hungary and Poland as well. In the case of Hungary, Poland, and Czechoslovakia the process of developing new markets is assisted in various ways by the EEC and by the most-favored nation status guaranteed by the U.S. Congress. The Western European orientation of these countries is strengthening day by day. The European relationships and western orientation of Bulgaria and Romania are similarly strengthening, although their future is more difficult to predict.

The agriculture of Eastern Europe is experiencing intense transformation. The success of these changes fundamentally depends on the agricultural economy of the given countries, but the help and understanding of western countries are needed as well. Undoubtedly, the reforming of Eastern European agriculture will become a rival. But, I am convinced about the mutually advantageous possibilities which will be offered by the democratic Eastern European countries with their opening market economy for the agriculturally developed world.

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Agricultural Reform in Developing Countries: Reflections for Eastern Europe

Avishay Braverman and J. Luis Guasch

Eastern European countries and the USSR are embarking on a breathtaking political and economic transition. They are venturing into uncharted economic territory encumbered by institutional rigidities, property rights dilemmas, high external debt, nonconvertible currencies, and inadequate safety nets, all of which pose severe problems for traditional macroeconomic and price reforms. The move toward a market economy has shocked the stagnant and deceptively stable socialist system, bringing unemployment and inflation.

The people of these countries, however, are not the only ones who are moving into uncharted territory—so also are economists usually designated "Western," i.e., those working in the tradition of economic theory that developed unconstrained by strict Marxist dogma. Modern economic theory offers little insight into the dynamics and institution building necessary to move from a centrally planned to a market economy. Our Arrow-Debreu paradigm even in its most modified version, allows analysis of small changes in a market economy. It assumes the existence of well-defined property rights, financial and marketing institutions. In their absence, our ability to predict the impact of major reforms, such as freeing the price system, is limited.

The reform of formerly centrally planned economies involves freeing the price system, developing a competitive environment, and privatizing many of the state-owned or controlled assets and services, while simultaneously generating the social, economic, and legal infrastructure that undergirds a market economy. These processes require varying time dimensions in an atmosphere of political uncertainty. Any *ex ante* analysis of the transition in Eastern Europe and the USSR should, therefore, be approached with the utmost humility and with the knowledge that we have many lessons yet to learn as we expand our theory to comprehend this phenomenon.

The experience of developed and developing countries offers some lessons relevant to the transition. In this paper we focus only on lessons relevant to the agricultural sector. The agricultural or rural sector in developing countries is important. In many countries it is still the main engine for growth and a major contributor to foreign exchange. The rural sector engages between 50% and 80% of labor in most developing countries and contributes more than a quarter of gross domestic product (GDP). Most of the poor in developing countries still reside in rural areas. Agriculture has traditionally been subject to discriminatory practices, through exchange rate, price, and tax policies known together as the urban bias.

Many developing countries have attempted to remedy the problems caused by the urban bias plus the budget deficit, balance of payments problems, and massive external debt by embarking on the so-called process of structural adjustment. In response, international financial institutions, in particular The World Bank, have generated a new lending mechanism, the structural adjustment loan conditioned on various policy reforms. We prefer to view these loans in a broader context, since structural adjustment should be seen as a process of ongoing policy reform. The areas of reform include monetary and fiscal policies, exchange rate and domestic price reforms, institutional reform (especially in areas of credit, marketing boards and land and property rights), and policies to improve technology transfer and adaptation. In addition, special attention has been given to programs to pro-

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tect the poor, with an insufficient degree of success. Adequate investment in physical and human infrastructure, including health, education, and nutrition, is critical to supplement structural adjustment programs, and these investments have a high payoff, particularly for the poor.

The process of reform in developing countries differs from that in Eastern Europe and the USSR because the physical infrastructure, human capital, and cultural context that comprise the initial conditions differ. The differences limit the degree to which the less developed country (LDC) experience generalizes the Eastern Europe and the USSR. The suppression of markets in the former socialist countries is greater than in the LDCs. The distortions within the agricultural sector are more massive and more difficult to measure without meaningful prices and exchange rates. The urban bias in aggregate has been less in the post-Stalinist period than is the case in LDCs because subsidization on a large scale through the state budget and the banking system has allowed producer prices and earnings to rise even though labor productivity is low. The urban bias in several countries, most notably the USSR, has increased in the transitional period as controlled producer prices have fallen behind increases in the general price level. The bias is still less than in many LDCs, however, and the large subsidies of recent years affect rural people's evaluation of the gains and losses that the transition will bring. The implications of these differences in initial conditions for the two types of policy reform, structural adjustment in developing countries and transition to post-collectivist market-oriented agriculture, will be discussed below.

Getting the Prices Nearly Right

Four issues usually must be addressed in an effort to get the prices nearly right: (*a*) a credible correction of the exchange rate must be achieved; (*b*) relative prices within the agricultural sector must be adjusted; (*c*) the transmission mechanism that links domestic to international prices and consumer to producer prices must be changed; (*d*) the needs of vulnerable groups must be monitored and addressed.

Achieving A Credible Devaluation

The intent of devaluing the exchange rate is to increase the relative price of tradables with respect to nontradables. Given the prevalence of urban bias, this tends to increase agricultural producer prices at the expense of incomes of urban residents. One clear lesson on devaluation that has been learned is that devaluation will achieve its original purpose only if there is political commitment, manifested through fiscal discipline, to change the rural-urban income distribution. If the government offsets the devaluation by expenditure that increases the income of the urban sector, particularly the government sector, the results will be the nullification of the devaluation and generation of cost-push inflation (see Braverman and Kanbur for an example in an African context).

The Importance of Relative Price Changes

A uniform price shift, such as that which takes place in devaluation, is important, particularly when urban bias is great. In both developing countries and the former socialist countries, however, change in relative agricultural prices can be more important because the distortions in these prices are quite high. Moreover, when the aggregate supply elasticity of output and employment in the agricultural sector is low, the response to a uniform shift in prices, as is achieved through devaluation alone, may bring modest welfare gains. The greater impact on the budget deficit, foreign exchange, and on the distribution of income derives from response to adjustment in relative prices of key commodities. In addition, because the aggregate response has very high own and cross effects, the costs of inappropriate relative prices within agriculture are high, and the welfare gains to remediation correspondingly great. In assessing price reform which involves tradeoffs, we empirically use estimated elasticities, and the newly reformed centrally planned economies present a real dilemma. We do not have price series that are meaningful for the generation of these elasticities. We are forced, as is the case in analysis of many data-poor developing countries, to resort to guesstimates and judgment.

In the case of Eastern Europe and the USSR, exchange rates have historically been grossly overvalued, but their impact on resource use has been muted by bureaucratic restrictions and hidden interventions. Devaluation is essential, but the response to a uniform price shift and to changes in relative prices will be modest unless the instruments of bureaucratic intervention are also removed. Much of the gain from price reform (both devaluation and changes in relative

prices within the agricultural sector) will come from removal of distortions in regional comparative advantage achieved through price bonuses and assignment of quotas. In the former socialist countries, the removal of direct bureaucratic costraints on agents' decisions is an integral part of successful price reform; price reform and institutional change are linked. In LDCs the potential direct impact of remediation of price distortions is greater, although there, too, institutional changes promoting competitive behavior, such as the removal of monopolistic marketing and procurement boards, are essential.

Producer Prices, Consumer Prices, and International Prices

The usual prescription for price reform has been to move domestic prices toward international prices. Many people question this remedy because world prices are distorted. International prices for agricultural commodities are low in part because of the subsidization of agricultural producers in the EEC, the United States, and Japan. These price subsidies stand in the way of shifting comparative advantage in agriculture toward the developing countries. Moreover, current price support policies in all countries provide income transfers skewed toward large, more commercial, farms, and they encourage inefficient use of inputs, such as fertilizers, thus contributing to environment degradation.

East European and Soviet producers also suffer from these policies of developed countries. A breakthrough in the GATT negotiations through reduction of subsidies and quotas will improve the lot of their agricultural sectors. Therefore, strengthening the momentum of the negotiations on trade liberalization is very important to the long-run success of the reform process in Eastern Europe. The removal of relatively cheap subsidized imports, however, will exacerbate in the short run the difficulties of economies in transition in meeting the needs of their most vulnerable consumers.

Whatever the outcome of trade negotiations, small countries have to take international prices as determined by world markets, and policy reform should direct domestic prices towards international prices. This does not imply, though, a dogma of immediate equalization of domestic prices with international prices. Rather, we advocate assessment of tradeoffs involved in price reform in terms of government revenue, foreign exchange, and the real incomes of different groups. The reality of LDCs often implies a limited set of instruments for raising revenue and influencing income distribution, and therefore price reform must on occasion address conflicting objectives.

More specifically, domestic prices may diverge from international prices for several reasons: First, when a country exerts market power over international prices, the need to use marginal revenue translates into the need for an optimal tariff (tax). This special case applies to very few countries and a few primary commodities, and often the degree of market power of individual countries is overstated. This argument is irrelevant to the small countries of Eastern Europe but may have some relevance to Soviet wheat imports or eventual exports.

Second, the presence of significant price volatility might force the government to deviate from the full transmission of international prices to the domestic economy. Maintaining stable prices has importance for the macroeconomy by reducing the impetus for cost-push inflation and swings in government revenue and foreign exchange. Moreover, price stabilization can protect the very poor from transitory movements in real income below subsistence level. The macroeconomic consequences and protection of the very poor are probably more important than some of the microeconomic considerations which have received most of the attention of research on the economics of price stabilization up to now (Newbery and Stiglitz, Kanbur, Braverman et al.).

The third justification for price intervention involves subsidies of industrial countries. A developing country facing a reduction in world prices because of subsidies or other factors may be reluctant to pass these prices on to farmers if the reductions are deemed temporary. The motive is to avoid the adjustment costs of moving out of an activity with expectations of returning to it later. Supporting prices during periods of transitory decline may be justified to maintain production and employment in agriculture, but only if there is a strong consensus that the decline is transitory and the adjustment costs are high enough. Although price stabilization programs have often been costly and inefficient because of their misuse, the concept cannot be brushed completely aside. There is a need to look for an appropriate mechanism for income insurance and/or price stabilization devised in more effective ways. Given the absence of risk insurance markets together with producers' and consumers' inexperience in managing risk, the costs of variability may be higher in

the transition. Therefore this issue should be reopened.

Fourth, political and administrative problems may make income tax and other broad-based taxes impractical, particularly in some poor developing countries. The government thus has difficulty raising revenues to finance essential public expenditures, e.g., for infrastructure and poverty alleviation. In Eastern Europe and the USSR, the political and administrative problems associated with introduction of a new tax system are formidable but do not justify the substitution of commodity taxes for a more modern fiscal system. The difficulties with the changeover to a new tax system are transitional, rather than endemic, and delay in the introduction of more appropriate taxation will simply build new distortions into the reformed economies.

Protecting the Vulnerable

In developing countries, policy reforms in agriculture often imply raising food prices to provide better incentives to producers. Eliminating food subsidies reduces urban income in relation to rural income because food prices go up. These changes require political will because the urban sector is much more politically sensitive and influential than the rural sector. They raise the distributional issue of how price reform adversely affects vulnerable segments of the population. In Eastern Europe, the same problems can occur, as the recent severe increases in food prices in Poland have demonstrated. Several important differences between Eastern Europe and developing countries should be noted, however. In the former, basic nutritional needs have been met in general, and expectations and standards of living are higher than in many developing countries. The changes in Eastern Europe, however, are of tremendous magnitude; economies that have known little unemployment will experience a great deal of joblessness. Many real wage earners are experiencing declines in their real income because of increasing prices. The decline of real wages is exaggerated, since during the period of low prices many consumers experienced quantity rationing and resorted to black or free market purchases at higher prices. Safety nets, such as social security, have yet to be created. Agricultural employment is proportionately less than in most LDCs, and changing the rural-urban terms of trade may thus adversely affect a large number of people in urban areas.

Despite the differences in their circumstances, the experience of poorer segments of society in developing countries is relevant to that of Eastern Europe. In LDCs higher food prices hurt the urban poor, landless farmers, and small farmers with a negative marketed surplus, at least in the short run. To protect these vulnerable groups during the adjustment, targeted programs are desirable and have been implemented. The track record for such programs in developing countries during the last twenty years has not been very good, however. They should be advocated only when the appropriate political will and administrative capacity exists in order to avoid corruption and mismanagement of resources. Otherwise, it is still advisable to resort to subsidization of commodities that the poor significantly consume much more than do the rich (that is, inferior goods). The financing and implementation of large safety nets during the adjustment process of the Eastern bloc will require large amounts of capital transfer from the Western world, including international organizations. The challenge will be to design, monitor, and implement these programs to guarantee that large sums of money will be appropriately distributed to the needy population during the transition.

Institutions

Credible price reform can achieve the desired price response only if supplemented by institutional reform to provide for well-defined property rights, easy access to capital inputs, financial institutions that distribute credit effectively, and competitive marketing boards that allow producers rather than institutions to retain rents. There is also a need for a coherent policy on research and development to induce innovations and to diffuse technical knowledge and information through extension services. Without such policies the potential gains of price reform probably will not be realized (Chhibber). Crops have to reach markets quickly, and only farmers with access to credit will choose the right mix of inputs or exert the right amount of effort. The provision of public goods, like water and irrigation systems as well as extension services, can be a most effective way to increase yields; but one can hardly expect individual farmers to invest much in them. The evidence suggests, however, that many countries, particularly low income Sub-Saharan African economies, have seen the efficacy of price reforms undermined by the pres-

ence of severe infrastructural constraints and market rigidities. In consequence, many structural adjustment programs should have policy components addressing those issues.

Credit, Financial Institutions, and Marketing Boards

Improved access to credit in LDCs was intended as a major policy instrument to accelerate development in the rural areas and to improve the income distribution between rural and urban residents. In addition, it was advocated as a second-best remedy to counter the common discrimination against agriculture through the urban bias in tax, price, and exchange rate policies.

The record of companion policies to price reform, particularly on credit and institution building, is disappointing. Over the past thirty years, massive amounts of credit, most often at subsidized interest rates, have been channeled to rural sectors in developing countries. But more often than not, those subsidies have benefitted the wealthier and influential farmers. Little formal credit reached the small farmers. Also, many institutions created to support the agricultural sector, in particular formal credit institutions, suffer from inefficiency and ineptitude, engage in arbitrary practices, and lack financial viability (Adams; von Pischke, Adams, and Donald; Braverman and Guasch).

The above-mentioned shortcomings in performance of financial institutions, however, could easily apply to the developed countries. The Savings & Loan crisis in the United States will probably end up costing $250 to $500 billion, an amount that dwarfs the obligations of even the most debt-ridden LDCs. The creation of long-term accountability in financial institutions is becoming a global issue. Eastern Europe must learn from the failure of incentives in many financial institutions in LDCs and the developed world and build credible mechanisms for monitoring, enforcement, and accountability. Banks in the socialist system were essentially agencies for transmission of funds and fulfilled few of the functions of full financial institutions in a market economy. Therefore, technical assistance from developed countries will be necessary in order to develop basic skills in the technology of banking, accounting practices, and generation of financial instruments. Financial institutions must be created immediately, for without them, a market system cannot function.

The needed institutional changes go beyond the financial sector, and, as argued above, are critical in the area of marketing. Reforms in marketing boards and procurement agencies are urgently needed to promote competition, since many of these organizations exhibit monopoly power and overly tax the farmer. Their noncompetitive behavior reduces farmers' supply response and inhibits improvement in the rural sector. Experience in developing countries has shown that attempts to interfere directly with supply through rationing, licensing, targeting, and other direct controls have been open to abuse. At best, the attempts breed inefficiency. At worst, they increase monopoly power, increase inequality, and encourage corruption. The key characteristics to strive for are accountability, noninterference, and responsiveness to market forces which will generate competitve behavior.

Property Rights, Land Tenure, and Privatization

Structural adjustment policies often involve reassessing property and land rights as well as titling the land. A major issue here is whether and how the absence or ambiguous definition of land rights harm agricultural productivity. One usual line of reasoning is that when land or property rights are not well defined, farmers are reluctant to sink fixed (irreversible) investment or to make long-term investments in their land, even though doing so is socially efficient. Another is that farmers' access to credit is hampered because their land is not accepted as collateral.

Evidence of the reality of these links is ample. For example Feder's case study on Thailand shows that the lack of land title prevents small farmers from access to credit and induces underinvestment of capital. The policy implication is that property rights should be fully exclusive, transferable, alienable, and enforceable to facilitate the development of an active land or rights market. Property rights or long-term land use rights with these characteristics induce efficient and higher levels of labor and management, as well as greater investments to enhance land yields. This point is very important in the East European and Soviet context because these countries enter the transitional period with a strong ideological bias against fully functioning markets in land. Restrictions on land markets will constrain the extent to which reform in the financial sector can move forward because

the state will be forced to retain an active role in agricultural lending (Brooks).

A point to consider in the land privatization process is what should be the level of land fragmentation. Of course, that could be left *ex post* to the market to resolve, but that could take years and large transaction costs to bring the desired changes. An argument for maintaining the current size, where the average farm size is over 1,500 hectares, except in Poland, is that it would allow for the reaping of the existent and significant economies of scale in agricultural activities, giving those countries an advantage over the countless smallholdings of the EC, provided that the managerial and agency incentive problems are accounted for.

The developing countries offer few lessons on the particular issues of farm reorganization and privatization of land relevant to Eastern Europe and the USSR simply because few collectivized on the scale of the socialist countries. The available lessons lie mostly in the successes and failures of the Chinese and Israeli experiences, but the generalizations are limited. In China price reform and division of the land (albeit suboptimally) brought an immediate supply response due in part to a divisible technology amenable to small-scale production. The Chinese experience suggests that uncertainty as to the duration and renewability of the land contract limits investment and constrains long-term growth (Lin). The Israeli experience with long-term marketable contracts in land also offers some lessons (Zusman; Kislev, Lerman, and Zusman). In Israel long-term leasing of land has provided security of tenure adequate for investment and producers have jointly contracted for use of nondivisible technology. The Israeli agricultural sector, however, has been plagued by financial overextension because of the existing unlimited joint liability both among members and among cooperatives that lead to significant "free-riding."

In addition to land reform, the privatization of agrarian enterprises is at the core of the agricultural reform in Eastern Europe. When, where, and how to privatize these organizations, and how to structure efficiency and fair access into the process present dilemmas for the former socialist countries that the LDC experience does little to elucidate. The public sector in most developing countries is of course proportionately smaller than in Eastern Europe. Many developing countries established state enterprises with the intention to correct market failures and improve income distribution. Although some state enterprises, like the Kenyan Tea Authority and the Botswana Meat Commission, are relatively well run, many public enterprises in developing countries and throughout Eastern Europe and the USSR are statutory monopolies or are given advantages over private concerns through open or indirect subsidies. In addition, they often lack competitive or fiscal discipline as they perceive themselves—unfortunately rightly so—as being subject to soft budget constraints (Kornai). The absence of financial discipline shelters their survival and riddles them with inefficiencies and inequities. Some developing countries have in response moved haltingly toward the privatization of large state complexes. The results of their cautious approach have been mixed. In Malaysia and Togo, selective privatization has been vigorous, but these countries have been the exceptions despite widespread disenchantment with the public sector.

The efficiency argument for privatization or divestiture emphasizes the potential benefit to the consumer from lower production costs. Those benefits can be reaped and passed to the consumers only if there is a competitive environment and a supporting infrastructure. Privatization in itself will not bring competition and improved performance. In Poland, despite much privatization in agricultural production, systemic and institutional impediments in extention, credits, input supply, and marketing depress agricultural productivity. Noncompetitive behavior in marketing prevents the private sector from benefitting from the superior incentives of private ownership. Moreover, transferring monopoly power from a public enterprise to a private one will transfer value added from one privileged group to another (or sometimes to the same people in larger amounts!), but will have ambiguous net impact on consumers and on total factor productivity.

The question of how and when to privatize is a complex one. The conditions under which privatization can fully implement the social objectives of equity and efficiency are restrictive. Economic theory convincingly argues for the allocative superiority of competition, but it is much less forceful, if not ambiguous, about the superiority of private ownership. There is a cost to privatization, as we have learned through the principal agent literature. In providing incentives, the government receives less than the expected discounted value of enterprise profits, because of risk aversion, informational constraints, and capital restrictions. Moreover, some objectives might be very difficult to obtain in

the course of privatization, like the right risk taking, the socially optimal innovation, and the equitable division of capital, particularly in these societies where over forty years of collectivization have significantly undermined the psychological prerequisites for private undertakings.

The appropriate balance between the public and private sectors hinges on establishing who has a comparative advantage in the productive or service activity. If measures can be taken to ensure a competitive environment—a large determinant of efficiency—it would be foolish to claim that no government intervention could improve welfare. Opening formerly closed economies to foreign competition can induce competitive behavior even if the domestic industry remains concentrated.

Given the severity of the price and market distortions affecting Eastern European countries, it is difficult to determine *ex ante* which state enterprises would perform effectively under a bona fide market system and which would not. The issue of privatization illustrates our need for humility—if we could distinguish the viable from the nonviable enterprises, which should be privatized? The bankrupt ones, trading fiscal solvency for higher unemployment? Or the potentially profitable ones, releasing profits where they can grow under better incentives, and retaining weak firms under the shelter of the state's portfolio? If it is possible to harden the budget constraint and change managerial incentives, privatization may not be necessary. The credibility of the commitment to a hard budget constraint is difficult to promote, however (Brooks).

Equity and fairness are key issues in the privatization debate and must be considered along with efficiency. We have learned from developing countries that severe inequities can result on two fronts. First, equity will suffer if small, powerful groups within the society are allowed to gain ownership of large amounts of property. Conversely, East Europeans and Soviets now face the rare opportunity to put in place a relatively equitable distribution of agricultural assets and wealth that minimizes the need for costly contractual negotiations and can serve as a foundation for future growth (Stiglitz). Second, a situation in which the prices of capital are much lower than the actual market valuation can result in the inappropriate large transfers to foreign interests with greater access to capital. Even if valuation is correct, wealth will pass to foreigners if domestic citizens have poor access to international capital markets.

The distribution of the gains from privatization within the country depends on the distribution of information and access to capital markets, which often privileges people well placed in the old order. Valuation also critically affects the distribution of gains. Care should be exercised to avoid "spontaneous privatization," or the illicit or unfair capture of sale proceeds or asset value by the former managerial class. Denying ownership to former managers, however, eliminates a class of people who presumably are relatively better trained to run the enterprise. If the enterprise can be fairly valued, the problems of spontaneous privatization are reduced, but not eliminated.

Research, Extension and Technology

Much agricultural growth can come from new technologies. Research generates innovations, and extension brings them to the field. Research and extension are public goods, and the private sector alone will underinvest in them without government intervention. Most developing countries have neglected agricultural research, as is exemplified by the lack of government commitment to research, budget cuts, and a low level of funding for operational expenses. Research and extension expenditures have barely exceeded 1% of the value of agricultural product in most developing countries, whereas three times as much is allocated in the industrial countries, where the relative importance of agriculture in the national economy is lower. Perhaps the shortage of trained scientific and technical staff and the difficulties in measuring positive returns in extension and research investments in the short run have been some of the causes. The developing world has consistently shown lack of a coherent strategy, the lack of a review of the status of research for each agro-ecological zone, and the lack of an evaluation of the expected net gains from research.

The most common type of research has been applied or adaptive. It is less costly, more oriented to quick results, and essential because research developed elsewhere cannot be directly transferred without some adaption to local conditions. But even where successful research programs have been developed, problems have occurred in the dissemination of those advances. Research and extension services have not always been linked.

East Europeans and Soviets can learn from the shortcomings in research and extension in the

developing world, but they can learn the same lessons from the poor returns to their own larger investments in agricultural research. Satisfactory links depend on cooperative attitudes among the scientist, the extension worker, and the farmer. Regional committee, joint or farm trials, having research workers function as subject matter specialists, running periodical in-the-field training sessions can all help in strengthening these links.

The experience of agricultural research and technology transfer in the developing world is not one of uniform failure. There have been significant successes, as well, and many of these have been achieved in coordinated international efforts that link participants from many countries of the developed and developing world. Linkages with the international scientific community can be expected to have a higher payoff in Eastern Europe and the USSR than in the developing world because the initial investment in basic scientific knowledge is higher.

The Environment

Environmental degradation is one of the more ominous problems facing Eastern Europe and the USSR, and in this area the experience of LDCs offers an important cautionary note to temper the enthusiastic rush toward markets in the former socialist countries. In developing countries, a focus on growth without careful consideration of the long-term consequences has resulted in pollution, erosion, and consumption of nonrenewable resources. The classic problems of externalities have made markets myopic with regard to the needs of future generations and very hard on the environment. Given the inherited environmental degradation, the former socialist economies cannot afford leisurely lessons in environmental protection. Technical assistance will be necessary in order to find ways drastically to reduce industrial pollution, deforestation, and soil degradation.

The severity of the environmental degradation associated with market-oriented growth raises an important question: Should the wealthier countries subsidize poorer nations to encourage them to choose an environmentally more responsible path? This question arises more concretely when a wealthy neighbor provides tied assistance to a poorer neighbor, with the objective of reducing transboundary pollution. In both cases instruments must be created to transmit the incentive to cease pollution to the agents actually engaged in environmentally destructive behavior. This involves creation of instruments such as marketable pollution permits, but these will achieve the desired effect only if indirect effects on employment are included, as well.

Conclusions

The transition to postcollectivist agriculture presents unprecedented opportunities and dilemmas. The experience of developing countries has much relevance for the countries of Eastern Europe and the USSR, but unfortunately it offers no magic formulas or guaranteed solutions. The scope of change is greater than that attempted in the structural adjustment programs of the developing world, and, because of its comprehensiveness, the potential that the parts will fit together is greater. The dilemmas and pitfalls are correspondingly large. A central dilemma is the tension between commitment and flexibility. Economic agents must believe that the government will and will force others to play by the new rules. Yet the rules must occasionally be changed or adjusted as ignorance clears or circumstances adjust. The merger of flexibility with credibility is indeed an art.

In this process of artistic science, modern economic theory is of limited help. Rarely have economists encountered the kind of consciously undertaken, sweeping changes that Eastern European societies and the USSR have proposed including the creation of new legal, political, and social infrastructures. Western technical assistance with the support of international financial institutions can be effective only if professionals of the East and West work together since this is a process of joint learning, not a pure transfer of knowledge.

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Implications of the Structural Adjustment Experience in the Developing World for Eastern Europe: Discussion

Gordon C. Rausser

The presentations in this session were far more interesting than the formal papers. I make this assessment in a world of limited information, as I have only just received Csáki's paper and have yet to see Braverman's. This condition leaves me with the freedom to pursue my own thoughts rather than evaluate two papers, one of which I can only imagine from the verbal presentation. While presenting my own thoughts, however, I will make some reference to the fine presentation of Csáki and the comments and observations of Braverman.

Communism has failed. In the aftermath of last year's extraordinary events, it is clear that the ideological appeal of communist political systems has been irrevocably damaged. Throughout much of Eastern Europe and the donor community, there is a clear vision of where each country wants to arrive; unfortunately, there are few clues about the path that should be traveled to get from here to there. Csáki informs us that the most important task is to develop a market-oriented and competitive agricultural structure. Yes, but how? To be sure, some individual policies that have formed the basis for successful market economies, if introduced with the wrong timing or in isolation from other reforms, can make an inefficient economy perform even worse.

For each of Csáki's five major issues, he outlines a number of policy alternatives. As with Csáki, Braverman's presentation largely focuses on the policy instrument space: the right setting of producer prices, consumer prices, pricing of credit, allocation and ownership of land, and so on. It is my view that prescription in this space, the selection of policy instruments, is misguided and is most likely to lead to the wrong path in getting from here to there. Instead, our prescription should focus on the underlying constitution that establishes the guidelines and mechanisms for economic, political, and civil freedoms. In this setting, we must be concerned, for example, with more than simply the rule of law, but the choice of law and the extent of liberty as well. This includes a selection from among the legal traditions that rule mankind: civil law, common law, Oriental law, Hindu law, Muslim law, and socialist law. In this choice, as in all constitutional economic selections, the political-economic landscape, the culture, and the customs of the country in question must be formally recognized.

Experience in the Developing World

The above observations are based on the empirical evidence that has emerged in developing countries. This evidence is drawn from developing countries which differ not only in the details of their economic policies but also in their underlying constitution and institutional framework, the extent of freedom and liberty, and their entire approach to growth and development. Serious inspection of this evidence reveals that (*a*) "getting the prices right" or "setting the property rights straight," or both, is not sufficient for an economy to reach its full potential; (*b*) bad governments and institutions have been a serious, if not the most serious, obstacle to economic development; and (*c*) all public sectors pursue a mix of predatory and productive activities—bad governments emphasizing the former and good governments finding a way of promoting the latter.

Available evidence reveals that the more centralized the system of economic decision mak-

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ing, the more opportunities are presented to officials to behave in a predatory manner. The degree of centralization in economic decision making is one of the characteristics that distinguishes those countries that were successful in achieving desirable economic reforms from those who failed to do so during the 1980s. In Bolivia, for example, one of the least-developed and poorest countries in South America, a large informal sector existed, while state intervention and control was confined mainly to an obsolete formal sector. In Argentina and Brazil, computer-assisted bureaucratic administration and control were overlaid by large and pervasive systems of quasi-governmental production and resource allocation. These systems, in turn, created their own large and powerful constituencies. They also created enormous opportunities for corruption and graft. The general rule is: He who decides who gets subsidized can get very rich, especially in an economic system characterized by central administration and control.

The degree of centralization in Eastern European agricultural sectors concerns both Csáki and Braverman in terms of the ownership, operation, and distribution of land resources. Based on the experience in developing countries, some economists have identified equity of land distribution as an empirical characteristic useful in explaining economic performance across countries. Here, the Latin American economies and the Philippines—where land ownership is highly centralized in patterns inherited largely intact from colonial periods—may be contrasted with the model economies of East Asia, such as Taiwan and Korea, or even Japan. In Korea and Japan, land redistribution was instituted by the allied powers following World War II. Land ownership in Taiwan began to change when the Nationalists took over the island in the 1930s. But land distribution, itself, is hardly an explanation for the far superior, postwar economic performance of the East Asian economies.

Instead, the most intriguing aspect of land distribution is what is implied about the political influence of the land-owning, agricultural factions in each country. An alternative hypothesis is that, although land redistribution partially rearranged the old political-economic alignments in Korea and Japan, this was not sufficient to allow new export-oriented policies (e.g., competitive exchange rates and low tariffs) to be implemented without significant opposition from the domestic agricultural factions. In Taiwan, too, the postwar agricultural sector was closely aligned with the Nationalists and was clearly a faction to be reckoned with. Each of these countries instituted economic policies to compensate agricultural interests (via high-tariff and nontariff barriers) in return for the freedom to proceed with *export-oriented* policies in the balance of the economy. This policy mix has proved to be remarkably stable and survives largely intact to this day in each of those countries.

Although traditional or in-power factions may have a stake in opposing change, often there are no viable alternative factions within the political system. Peruvian Hernando de Soto details the enormous political and institutional hurdles that must be overcome by individuals and businesses when they are not a part of the dominant political-economic faction. His prescription is to mobilize alternative factions so that they can represent their own interests. However, this may not be feasible without political and institutional reforms to remove the barriers to such advocacy. Even in a democracy, alternative constituencies must be enlightened as to what various policy options would imply. They must also be given the means to voice their concerns and interests within the constitutional process. And there must be checks and balances that limit the ability of any single faction to gain and retain unchallenged political and economic control.

Available evidence suggests that, when domestic constituencies have emerged that favor and benefit from new policies, reforms have been sustained and credible. Occasionally, special inducements, e.g., export subsidies and export-processing zones, have succeeded in creating those new constituencies. Often the objective is not to achieve a trade-neutral regime but, instead, to bias the system in favor of exports, at least temporarily, in what might rightfully be called redistributive governmental policy making. This policy, in isolation, however, has not generally been successful. Once again, it is crucial that comprehensive economic reforms be designed covering the mix of policies across all sectors as well as fiscal, monetary, and exchange-rate policies. When accompanied by appropriate exchange-rate and macroeconomic policies, special inducements can assist in sustaining export-oriented policies in the initial stages introducing structural reform. Successful examples of this tactic in the 1980s include the Dominican Republic and Costa Rica.

It must be acknowledged that the best examples of successful economic developments in the 1980s were not nascent democracies but, rather, holdover authoritarian regimes. Chile,

Thailand, and Korea are the most often cited; examples from earlier decades might include Hong Kong, Taiwan, or Singapore. Yet, the overwhelming weight of empirical evidence in modern times suggests that the most open and democratic societies are the most successful economically and that free and decentralized markets are the most successful in producing sustained economic growth, a condition conducive to political liberty. Sustaining economic success in the long run, in fact, may require democracy. Certainly, there are no examples of modern industrial countries that have continued to achieve success in economic growth and development under authoritarian or totalitarian governments. Even in the short run, the civil, legal, and political institutions of democracy, in many cases, seem to be an important ingredient of success in the economic sphere.

Democratic systems sometimes produce extremely disappointing economic policies—hence the lure of authoritarianism. Likewise, there sometimes are significant instances of market failure that can be improved through nonmarket organizational structures, including governmental intervention and regulation (Csáki's reference to environmental protection). Depending on what one believes to be market failure, this reasoning, if taken to extremes, can imply central planning and economic control. Moreover, in many developing countries, as was the case recently in Poland, the pain of adjustment in attempts to move from "here" to "there" is often blamed on the new policies rather than on the failed policies of the past. If the distribution of political power leads to an unwinding of currently designed reforms, market expectations of failure will induce inflation, capital flight, hoarding, and so on. This has often led to reversals of experiments with decentralized economic decision-making reforms.

The irony is that dictatorship, far from being necessary for economic growth, may be its antithesis. In this instance, corrupt and inept regimes cannot be changed by the will of the citizenry. There is no better confirmation of this statement than the postwar experience of Eastern Europe under communistic dictatorship, or the postrevolutionary experience of Stalinist Russia. And it is also true that for every example of economic success among the authoritarian regimes of the third world there are several examples of failure. The distinctive feature of dictatorship is that, by its very nature, it is unaccountable to most citizens and their representatives. Although this may seem like an advantage when unpopular decisions must be taken that would be in the public interest, it also means that economic policies which hurt society generally but benefit a "crony elite" are immutable to change, at least through constitutional means.

In contrast, democratic pluralism can and does provide an important discipline on the performance of governments and officials. Democratic pluralism means a political and legal system that allows citizens to assemble and to speak out against and remove from office governments that do not serve their interests. Moreover, it means protecting their human and civil rights so that they can perform these responsibilities. Unless one is willing to believe that politicians and bureaucrats are inherently benevolent and wise, democracy is ultimately necessary for successful economic performance. In the final analysis, elections allow citizens (who may on occasion be confused about cause and effect) to replace inept and corrupt officials and governments that have pursued failed economic policies. An open polity may be the single most important underpinning for an open economy in the sense that diffusion of political power, ease of entry and representation in the political arena by alternative economic factions, the fair rule of law, and clear limitations on the powers of and access to governmental officials all facilitate the growth of decentralized and private markets. Productive economic reforms and capitalism flourish best in a climate of freedom and diffuse political power. In turn, diffuse political power is alive and well in a world of ample mobility and widely diversified asset portfolios.

Prescriptive Paradigm

To change the relative costs and benefits of adhering to old constitutions, institutions, and policies, it is generally necessary to form coalitions that stand to benefit from reform. In this context, what are the basic characteristics of a paradigm that allows meaningful prescriptions to be assessed? This paradigm must recognize that power is distributed among the various interest groups and that the maldistribution of power can blunt any and all reform efforts; it must recognize that governments can have some separate autonomy and can seek "leadership surplus"; it must provide an internally consistent framework which admits the possibility and necessity of accommodating various interests; it must conceptualize the bargains, pacts, compromises, and efforts that are undertaken to shape policies that

are acceptable, not only to those who have the greatest capacity to obstruct the policy but also to others who have stakes in the outcome; and finally, it must be the basis for an integrative framework that recognizes the joint determination of both predatory and productive governmental interventions.

Some of the above characteristics are self-explanatory, and some require elaboration. Leadership surplus is a crucial concept in this prescriptive paradigm and provides an alternative hypothesis to the theories advanced by Stigler, Becker, and others. In essence, leadership, much like institutions, can be induced by economic phenomena or external crises. What makes leadership for reform possible? Or equivalently, under what circumstances will individual agents and interest groups modify their rational self-interest and subject themselves to the "public interest?" Here, we can draw from other disciplines, particularly social psychology which has offered the hypothesis that interest groups are surprisingly willing to engage in obedience contrary to their own convictions when there is only a gradual escalation in actions they are asked to take. With each escalation, their previous action sets the norm for their current behavior. For those agents who have the power to obstruct reform, predatory policies can be offered as political compensation.

In the prescriptive paradigm, current policies are viewed as some rational outcome of the political-economic process—conditional, of course, on the constitutional and institutional structure. This political-economic process is one where the public sector plays a crucial role and in a fundamental sense must be part of the coalition that supports reform. In any organizational structure that might arise, the public sector is naturally exposed to attempts by various interest groups to exert their influence. In this framework, if all power does not reside with the leadership pursuing the public interests, organizational failures naturally arise. Accordingly, the prescriptive paradigm must balance market failures with organizational or collective action failures.

To minimize market and organizational failures, at the prescriptive core of the proposed paradigm is constitutional economics. The basic questions of constitutional economics are: Is the constitutional order of the country conducive to free inquiry and social experimentation, or is it fundamentally repressive? Does the constitutional order provide ease of entry into the economic system, the political system, an ease with which legal foundations of new institutions can be established? Does the constitutional order provide sufficient self-correcting mechanisms to limit excessive predatory governmental behavior? Does the constitutional order motivate agreement on basic values and processes for conflict resolution—a sense of civil order—to reduce the cost or risk of innovation?

Concluding Remarks

Appropriate answers to the core constitutional economic questions will allow a country to find a desirable path to get from "here" to "there." It will admit practical prescriptions for economic reform that take the political environment into account. In some cases, it will prove necessary to compensate interest groups with the power to impede reform. In other cases, an opening of the political system to the broader representation of alternative interest groups will prove to be the only means for sustaining effective economic policies.

Solutions at the constitutional core will allow the appropriate mix of both productive and predatory policies to emerge endogenously. The mix of policies must be comprehensive, covering not only policies for the agricultural sector but fiscal, monetary, exchange-rate, competitive, trade, privatization, as well as other policies. If the constitutional core is properly structured, we will not find privatization emerging without effective liberalization or the issue of ownership dominating an appropriate restructuring of incentives. Moreover, given the emergence of effective leadership pursuing the public interest, an appropriate response to the core questions can be expected to provide the foundation for endogenously determining the sequencing of reforms that will enhance credibility and sustain economic growth.

For the prescriptive space advocated here, there is much useful theory and empirical evidence. There are, of course, gaps; and there is much to be learned about the relationship between open, democratic societies and open, liberal economies. Furthermore, there is much to be learned about how democratic pluralism can provide an important discipline on the performance of governments and officials in setting economic policy as well as the role that democratic institutions play in diffusing political and economic power. As a result, for those of us who are interested in these issues, we are witnessing in Eastern Europe perhaps the greatest experiments

of this century on constitutional economic reform, institutional change, and the endogenous political-economic determination of public policy. In the final analysis, any prescriptions that we advocate as a profession, based on previous theories, empirical evidence, or new developments in economic thought, must heed the advice of the current IMF Director, Michel Camdessus, ". . . economic growth, in its broadest sense, is too rich in meaning, too complex, and too essential to mankind's future to be left only to economists."

Lessons Learned in Structural Adjustment Lending in the Developing World and Implications for Eastern Europe: Discussion

Robert Saint-Louis

Conditional program assistance, which has come to be designated as "structural adjustment" (SA), was and still is the order of the day in many countries in Africa and elsewhere (Tweeten, Mosley and Toye). Also, from both methodological and pragmatic viewpoints, the experience of several countries which perhaps, each in its own way, found themselves in the "obligation" of improving their efficiency through the removal of disincentives and economic distortions and by allowing markets to operate as freely as possible, is becoming increasingly recognized (Roberts; Asiedu-Saforo; Koester, Schafer, and Valdés; Jaeger and Humphreys).

The central questions raised in this session are (*a*) whether or not important lessons have been learned from those countries that have already sustained some of the pains of outward-driven and/or self-imposed SA, and (*b*) to what extent some of these lessons can be applied to emerging market economies of Eastern Europe.

This session was also to evaluate, I supposed, the specific needs of a few countries in Eastern Europe by way of structural adjustments for their agricultural sector.

First I will discuss very briefly three major points raised in Braverman's paper. Then I will also scatter here and there a few short comments on the general theme of this session. Emphasis will be put on stressing the fact that extremely important differences between the two speakers' views on the macroeconomic situations involved lead them to emphasize the prominence which must be given both to the original content and the specific sequencing of the rehabilitation treatments in SA.

The main points raised by Braverman are (*a*) the nexuses (which are still far from being perfectly clear) between SA, policy reforms in agriculture, and the rest of the national economy, and overall societal and political changes in the countries having undergone SA or presently undergoing SA, as well as in those countries which are in the post-SA stage, by World Bank standards, (*b*) the specificity of economic adjustments needed for the agricultural sector and the rest of the economy in Eastern Europe, and (*c*) the lessons to be learned from the Bank's experience in dealing with SA treatments in the developing world.

First, concerning the nexus between SA and their enshrining policy reforms in rapidly changing societies, Braverman takes a rather humble, yet ambitious, look at the World Bank's experience in the Third World. He describes it almost as a set of enterprises which were as much about part of a larger process of changing the third world as a constant attempt to understand it before coping with specific medium and long-term investment decisions.

Also Braverman reminds us that overall societal and political changes in the Third World must be perceived as being time-specific and location-specific sets of *ceteris paribus*, and the variability of each set will continue to make all economists uncomfortable including those making analyses for the World Bank and the IMF, I presume. Specific national situations in Africa, for instance, are on that regard totally different from those in Eastern Europe at the present time. For the 1980s in the Third World, Hettne's opinion that the manifestation of crisis and of economics of survival were dramatic but to a large extent "definable" despite the fact that different sets of specific problems overlapped and were so pervasive, seems to gain Braverman's agreement.

But how right is it to argue that the Eastern Europe crisis still defies definition? Braverman raises the question in his own way by emphasizing that it has already manifested itself in so

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many fields at the same time: trade (including agriculture), industrial development, employment, integration, cultural values and life-styles, etc.

Thus, how should one interpret precisely the host of reasons why, for instance, the Supreme Soviet postponed, in June 1990, a crucial decision to triple the price of bread (from 20 to about 60 kopecks)? And is there any economist, either in the USSR or elsewhere, who has yet a precise idea as to what total quantity supplied and total quantity demanded at the contemplated price will be after this decision is made? Braverman does indeed raise a set of troubling questions when one thinks of such nonmarginal policy changes.

Coming now to the second point, where specific characteristics of economic adjustments in Eastern Europe are examined, Braverman suggests that we all must be very humble economists because we basically lack both theories and practice as to how one country ought to go from control planning to a market-oriented economy.

In a sense, it is not at all surprising that in the USSR, for instance, most republics find it rational, at least in the short run and from a regional point of view, to charge world market prices for their "exports" (even for agricultural products which are presently subjected to severe international price distortions) and pay for their "imports" from other republics the existing Soviet prices.

Turning now to lessons learned, Braverman states that attention needs to focus on issues having to do with (*a*) external incentives, (*b*) issues of institutional reforms, and (*c*) transfer of technology in favor of the agricultural sector.

The main thrust of his argument seems to be that international prices cannot and should not be imposed upon countries undergoing SA, without full and strong support from various segments of the population in any given country. International prices, however, can be used as benchmarks for setting up internal prices by rightfully taking into account the true trade-offs between issues of real levels of income, distribution of revenues, etc.

For the sake of brevity, I will terminate this discussion by pointing out that I fully agree with Braverman's opinion that institutional reforms must give a pivotal role and must put an important weight on "accountability," perhaps as the dominant variable in determining whether or not each institution and/or parastatal serves a useful purpose in any emerging market economy and perhaps even more so for those supplying agricultural credit to peasant economies.

In conclusion, the two papers illustrate the critical process that will lead both the third world and Eastern Europe to progress through SA. And perhaps the two speakers will appreciate being reminded that their own thinking seems to be best summarized by the following quote: "Profit seeking may get the economy close to its goals but even more specific instruments such as market prices serving as weights which set the social ordering of goods and services may prove more successful" (Aston).

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Arresting Renewable Resource Degradation in the Third World
(Duane Chapman, Cornell University, presiding)

Resource Degradation in Africa and Latin America: Population Pressure, Policies, and Property Arrangements

Douglas Southgate, John Sanders, and Simeon Ehui

Degradation of renewable natural resources in the developing world is taking a serious toll. Deforestation threatens biological diversity and could alter global climate. Soil erosion reduces the capacity of many countries to satisfy expanding demands for agricultural commodities. It also jeopardizes the benefits of water resource development. Deposition of eroded soil in reservoirs, for example, diminishes hydroeletricity production and reduces irrigation water supplies.

In spite of widespread concern over these environmental problems, analysis of resource degradation in poor countries is rudimentary. Simple Malthusian explanations, in particular, are widely circulated. Other than the general recommendation that human fertility be controlled, these explanations offer little guidance for the design of conservation strategies.

In this paper, a broader perspective is taken on the causes of depletive human interaction with the natural environment in Africa and Latin America. We find that the impacts of rural population growth and increased demand for agricultural commodities depend greatly on government policy and property arrangements. Examination of environmental problems in the Sahel, humid tropical Africa, and Amazonia reveals that the causes of resource degradation are similar in each of these regions.

The Causes of Environmental Degradation

As every student of economics knows, strong assumptions underpin the writings of Malthus and his contemporaries. One is that population growth is reflexive, accelerating whenever living standards rise above subsistence levels. In addition, the idea that agricultural technology never changes was widely shared two centuries ago. Together, these assumptions imply that shifts in the agricultural frontier are the only possible response to market or demographic "shocks."

Investigation of social realities in Africa and Latin America reveals that the behavior of rural people is much more complex than classical economists believed. Demographers find that increased rural population density induces various reactions. Fertility rates tend to fall as incomes rise. Relocation to urban areas or the agricultural frontier is also a possibility (Bilsborrow).

Similarly, the assumption that technology for crop and livestock production never changes has been rejected. In various ways, agricultural land can be used more intensively as rural populations rise or as demand for agricultural commodities increases (Boserup; Pingali, Bigot, and Binswanger). Intensification often begins with a decline in fallowing cycles, which usually diminishes soil quality. However, other options (e.g., increased employment of nonland inputs and a switch to new crops), which can enhance output without accelerating resource depletion, are also available.

The central point of this paper is that government policy and property arrangements have much to do with the countryside's reaction to market and demographic shocks. In many parts of the developing world, deforestation is a prerequisite for formal or informal land tenure and conversion of forests into cropland and pasture is directly or indirectly subsidized. In addition, research and extension needed for sustainable land intensification are inadequate in many countries. Under these circumstances, population growth and increased demand for agricultural commodities usually induce excessive migration to hinterlands as well as depletive forms of extensive settlement.

Resource degradation is acute in the three parts

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of the world that are the geographic focus of this paper. The Sahel, humid tropical Africa, and the Amazon Basin each feature unique natural and cultural conditions. Neverthless, the causes of depletive human interaction with the environment are similar. Population growth is a primary catalyst for expansion of agriculture's extensive margin as well as the abandonment of fallowing and other practices that maintain soil fertility. Inadequate investment in research and extension, governmental interventions that keep food prices artificially low, and other policies hindering agricultural development also accelerate the depletion of renewable natural resources. In addition, formal and informal tenurial regimes often discourage the adoption of conservation measures, encourage excessive land clearing, or both.

The Sahel: The Challenge of Sustainable Development of Semiarid Lands

World attention has focused on the region lying between the Sahara Desert and the coastal nations of West Africa since 1968, when an extended period of drought began. A classic Malthusian disaster has seemed to unfold in the Sahel. Populations have grown and soils with limited potential for agriculture have been brought into production. Resulting land degradation may have exacerbated harsh climatic conditions. Always marginal, living standards have failed to improve (Landell-Mills, Agarwala, and Please).

Social conditions and the physical landscape are not uniformly bleak in the Sahel. Almost one-fourth of the region's crop land lies in the Sudano-Guinean climatic zone, where rainfall exceeds 800 millimeters nine out of every ten years (Gorse and Steeds). Where soils are good, French development efforts involving agricultural research and extension, use of pesticides and fertilizers, and cotton price guarantees have yielded positive results. In southwestern Burkina Faso, for example, cotton and cereal yields have risen dramatically during the last two decades.

Demands on renewable natural resources are growing in the Sudano-Guinean zone. As control of river blindness has improved, for example, farmers have immigrated from drier areas. In addition, research is needed to improve conservation of soil organic material as well as the efficiency with which chemical inputs are used. However, sustainable development in the zone serves as a model for what can be accomplished elsewhere.

The challenge of sustainable development is considerably more daunting in drier areas farther to the north. Slightly more than half the crop land in the Sahel lies in the Sahelo-Sudanian and Sudanian climatic zones (Gorse and Steeds). In the former zone, where there is a 90% chance that total precipitation will be between 350 millimeters and 600 millimeters in any given year, soil fertility is low and it is difficult to retain water around plant roots. Also, cutting trees to plant millet accelerates wind erosion and aggravates sand blasting problems. Dregne recommends that forestry and grazing be the primary activities in the Sahelo-Sudanian zone and similar areas.

Nowhere in the Sahel is resource degradation more acute than in the Sudanian climatic zone, where rainfall is between 600 millimeters and 800 millimeters nine out of every ten years. Rural population densities are high. Soil fertility is declining because land is being given less time to recover between cropping cycles. As a result, millet (which grows better in poor soils) is being planted in place of sorghum, marginal grazing areas are being converted to crop land, and emigration is taking place. In addition, fuel wood is becoming scarce, which means that women are obliged to go great distances to gather it.

Sustainable development is possible in the Sahelo-Sudanian and Sudanian climatic zones. Unfortunately, resource conservation and income growth are difficult to achieve under current policies. The region's governments maintain low food prices for the benefit of urban consumers and ignore marketing bottlenecks responsible for price instability, generally, and the collapse of farmgate prices at harvest time, specifically. In addition, agricultural research and extension are not strong. Incentives to adopt high-yield, sustainable crop production systems, then, are weak. Farmers opt instead for extensive production, generally on fragile lands.

Finally, some property arrangements discourage environmental conservation. Under communal tenure regimes that prevail in the Sahel, a family wishing to plant crops is entitled to temporary use of a parcel. However, planting trees or even perennial crops is often regarded as an attempt to assert permanent individual rights in communal land. Under these circumstances, an institutional constraint on reforestation exists.

Humid Tropical Africa: Agricultural Expansion and Timber Extraction

Nearly one-fifth of the world's closed tropical forests are found in a belt that runs along the Gulf of Guinea and extends eastward to Lake Victoria. Changes in tree cover are modest in much of central Africa. Farther west, however, deforestation is very high, approaching 5% a year in the Ivory Coast and Nigeria (FAO).

All major catalysts for agricultural growth are at work in humid tropical Africa. The region's rural population is increasing, as is urban demand for food and fiber. Global market conditions are also appropriate for the establishment or expansion of export crop plantations.

As in the Sahel, the sequence of adjustments caused by population growth and increased demand for agricultural commodities often begins in humid tropical Africa with diminished fallowing. Land formerly lay idle for two decades between cropping cycles. In recent times, fallow periods have contracted to a few years. Continuous agricultural production is now the norm in some places, resulting in very low yields.

In most of the region, there are natural resource constraints on land intensification. Because soils tend to be thin and not very fertile, diminished fallow periods cause yields to fall off substantially. Applying fertilizers often compensates for only part of this decline (Lal). As land deteriorates, farmers colonize marginal hinterlands or migrate to urban areas.

A major threat to the forests of humid tropical Africa is the extraction of commercial timber. In and of itself, logging alters the natural environment. For example, using heavy equipment to remove commercial timber results in secondary losses. Logging is also a catalyst for agricultural land clearing. Roads originally constructed to bring in equipment and to haul out timber enhance access to tree-covered hinterlands. Furthermore, a logging site is relatively easy to clear for crop and livestock production. Because of these two positive impacts on rents captured by settlers, timber extraction accelerates colonization.

The strength of population growth, logging, and related catalysts for resource degradation in the countryside is enhanced by government policies. As in southeastern Asia, the terms of timber concessions generally do not encourage sustainable, intensive management of small forested tracts (Gillis). Similar to what occurs in the Sahel, extensive crop production on fragile lands, rather than sustainable land intensification, is the norm because research and extension are weak and commodity prices are low and controlled.

Governments also accelerate resource degradation by attempting to supplant local tenure regimes. Ignoring the distinction between common property (*res communis*) and open access (*res nullius*), they have failed to offer legal mechanisms for protecting communal land rights. Instead, attempts are often made to convert common properties into government lands and private properties even though the public sector's capacity to manage "its" resources and the legal infrastructure needed to enforce private tenure are both poorly developed. Weakening traditional property arrangements without providing a viable institutional alternative diminishes the incentives for forest dwellers to conserve natural resources (Bromley and Cernea).

The Amazon Basin: An Ideal Policy Environment for Deforestation

Appeals to save tropical forests take on special urgency when South America's Amazon Basin seems to be threatened. Satellite images from 1987, when the dry season was unusually pronounced, showed that agricultural land clearing and reclearing were widespread in Brazil. Fearing that the "lungs of the earth" were going up in smoke along with many plant and animal species, environmentalists, politicians, and rock stars called for quick action.

The true nature of environmental problems in Amazonia is not well understood by many expressing concern for the region. For one thing, the region's sheer size tends to be ignored. Since the nations of the European Economic Community could fit in Brazil's Norte Region (comprising six northern and northwestern states and territories), it should come as no surprise that vast stretches of forest remain intact there. Agricultural land clearing is significant primarily along roads penetrating the basin's margins. For example, one-fourth of Rondonia state, in the southern reaches of the Norte Region, has been settled by farmers (Mahar). Deforestation is also extensive in western Amazonia, just downhill from densely populated Andean highlands.

Just as it is erroneous to think that all land in the Amazon Basin will soon be cleared, explaining deforestation in the region in simple Malthusian terms is a mistake. The Brazilian government estimates that 8.6 million people (6%

of the country's population) live in the Norte Region. Of those 8.6 million, 4.7 million reside in cities and towns. Both intraregional migration and immigration from other parts of Brazil are directed primarily toward Manaus (which is a duty-free zone with substantial manufacturing), Belem, and other urban centers. The region's rural population rose at a 2.7% annual rate between 1987 and 1990. During the same period, its urban population grew 3.8% per annum.

A causal analysis of deforestation in the Amazon Basin, then, cannot concentrate on population growth. In addition, diminished fallowing on the part of an indigenous population of farmers is not a predominant form of land degradation in the region, as it is elsewhere in the developing world. To understand environmental change in Amazonia, one must examine how government policies and property arrangements influence the behavior of immigrants.

To date, economists have concentrated on government policies' contribution to deforestation. Subsidies for agricultural land clearing have been scrutinized. As Mahar points out, cattle ranchers converting forests into pasture used to receive cheap credit and other financial assistance. In addition, making it easy for all Brazilian farmers to avoid taxes has encouraged smallholders from the southern part of the country to sell off their land and move to the frontier (Binswanger).

Part of the blame for excessive encroachment on tree-covered hinterlands must also be assigned to low investment in the scientific base underpinning agriculture in the Amazon Basin. In Brazil, research and extension have been strong in other regions outside Amazonia. The same cannot be said of neighboring countries. As a result, crop and livestock yields in Amazonia are low, which means that growing demands for agricultural commodities tend to be satisfied through shifts in agriculture's extensive margin.

Furthermore, settlement of Amazonia causes excessive damage to the environment because the information base needed for rational colonization has not yet been developed. Resource inventories are incomplete and, although there has been successful experimentation with rice production on hydromorphic soils and with perennial crops, research and extension services available to farmers in the Amazon Basin are generally meager.

Along with subsidies and inadequate research and extension, inappropriate tenurial arrangements contribute to excessive land clearing throughout the Amazon Basin. As in humid tropical Africa, a classic open access problem arises wherever public sector claims on resources outstrip the government's capacity to manage its properties. "Illegal" settlement of the region's "paper parks" is a prime example.

Recognizing the consequences of an institutional vacuum, national governments grant settlers property rights. However, deforestation is usually a prerequisite for tenure in a frontier parcel. This arrangement encourages degradation of existing farm land as well as excessive encroachment on forests (Southgate). Even though they sometimes resist, indigenous groups and other long-term inhabitants of Amazonia, who long ago developed viable resource management regimes, have had to accommodate themselves to the outside world's wasteful property arrangements.

Conclusions

Population growth explains a large part of depletive human interaction with the natural environment in the developing world. To appreciate the importance of demographic pressure, one only needs to travel through Haiti and parts of Central America, where burgeoning populations are picking the countryside clean.

Accepting a simple Malthusian analysis of resource degradation, however, does not leave much room for optimism. Poor countries' populations are overwhelmingly young. With numbers of women capable of bearing children expected to rise for many more years, continued population growth is inevitable, even with the decline in fertility rates currently taking place in parts of Latin America and Africa.

It is fortunate, then, that simple Malthusian explanations of resource degradation do not entirely suffice. As pointed out in this paper, government policies and property arrangements have much to do with the use and management of natural resources in the developing world. Intervention in agricultural markets is widespread and research and extension are weak throughout Africa and Latin America. As a result, extensive agricultural production on fragile hinterlands, instead of sustainable land intensification, is the principal response to demographic and market shocks. In addition, existing tenure regimes often discourage tree planting and encourage deforestation.

Our analysis suggests that, before the long-term benefits of fertility control can be realized, policies and property arrangements must be

changed in order to foster environmental conservation. The difficulty of reform should not be underestimated. Powerful interests support many of the policies that discourage conservation. In the Sahel, for example, urban dwellers benefit from artificially low food prices which diminish the profitability of local cereal production and discourage the efficient management of environmental and other inputs to agriculture.

Effective reform is also a challenge because piecemeal changes in policy and property arrangements can be ineffective or even counterproductive. For example, if food and timber markets are deregulated but tenurial disincentives for resource conservation remain in place and no investment in research and extension is made, then wasteful exploitation of the countryside is likely to worsen. The chances for environmental conservation are significantly better when all policies and tenurial arrangements are reformed simultaneously.

As indicated in this paper, resource degradation is caused by similar factors in the Sahel, humid tropical Africa, and the Amazon Basin. Accordingly, many countries face the task of developing an integrated conservation strategy, one involving population control in the long term as well as policy reform and the development of suitable property arrangements in the near future.

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Resource Policy Reform in the Context of Population Pressure: The Philippines and Nepal

Wilfrido Cruz and Christopher Gibbs

The degradation of renewable resources in the developing world now threatens not only the economic prospects of future generations but the livelihoods of current users as well. For example, in many countries overcutting has so depleted timber stocks that the traditional contribution of the forestry sector to income and employment is starting to decline. Shifting cultivation in marginal lands leads to soil erosion and declining productivity. Watershed deforestation, from both logging and upland farming, has reduced the downstream irrigation and energy-generation potentials of water resources. While price and tax reforms can be critical ingredients in reducing the damage in commercial sectors, where large communities of individual resource users exploit common property or open-access resources, institutional changes are also required.

This paper presents a framework to incorporate the role of population growth and institutions in understanding the pressures for resource overexploitation. The problem of resource degradation is elaborated in the context of two Asian countries—the Philippines and Nepal—where population pressure on forestry and agricultural resources is substantial. The discussion shows that there has been a shift from a pattern of agricultural intensification and development to poverty and resource degradation. The last section suggests that the assessment of resource degradation must recognize this pattern and that policy reform must focus on the problem of population growth and inappropriate institutional structures.

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The Role of Population and Institutions in Resource Degradation

The role of government policy in altering the structure of incentives to reduce resource degradation can be substantial. Such reforms focus on tax or pricing policies where market institutions are fairly well developed and where resources are commercially exploited. However, in many rural areas of the developing world, the lack of well-defined property and market institutions and the presence of substantial population pressure on resources require that policy reform should also address changes in rules governing access to and use of natural resources.

The institutional problem is most apparent in forest lands. While most governments consider forest lands as part of the public domain to be kept under forest cover, their limited enforcement capabilities make these *de facto* open access resources. Such forest lands have therefore been rapidly converted to nonsustainable agricultural uses, causing severe erosion impacts. On-site production potential is reduced, and downstream siltation of waterways and agricultural lands is increased. Because of the environmental externalities associated with upland farming, simple privatization solutions are not efficient. Also, because of population pressure problems, exclusion of the neediest from large areas of the public domain is neither equitable nor feasible.

The need to recognize the role of migration and population growth in this context is especially important in South and Southeast Asia, where conditions of population pressure and increasingly tight land constraints prevail. Agricultural assessments show that Asian countries have higher population densities (FAO 1984)

compared with other parts of the world where economic policies, such as tax breaks for forest land clearing, may be the more important factor in resource overexploitation.

The Philippines: Economic Stagnation and Resource Degradation

In the Philippines, the pattern of population pressure on marginal resources include unchecked population growth, declining absorption of labor in both industry and lowland agriculture, and widespread poverty. With an area of only about 30 million hectares, the Philippines' population is about 62 million, with a growth rate of 2.4% (World Bank 1989b). The economy has had increasing difficulty in absorbing population growth, so unemployment and poverty are widespread.

In agriculture, expansion occurred in the accessible lowlands, first with rainfed cultivation and farmer-developed irrigation up to the early 1960s, followed by public investment in irrigation systems. Public irrigation development coincided in part with the arrival of green revolution technology in the mid-1960s. When the area that could be easily converted was exhausted, attention turned to dispersing green revolution technology more widely and to improving water management. However, the limits of both lowland expansion and intensification have now been reached, and farming has been moving to upland areas, resulting in deforestation. Forests now cover only about one-fifth of total land area versus an administrative target of 40%. Extensive agriculture and grasslands cover 40% of land area (World Bank 1989b). Actual cover differs from the jurisdictional classification which places about half of total land area under one government department.

Both upland farming and commercial logging are involved in the conversion of forest lands to extensive cultivation. Undervaluation of timber and rent seeking promote logging; in turn, the expansion of logging concessions encourages migration and shifting cultivation. The charge for timber is about $1.50 per cubic meter when international log prices are in excess of $200 per cubic meter. Thus, rents were about $60–$140 per cubic meter for 1987 (De los Angeles and Lasmarias). Surpluses motivate the continuing demand for logging concessions, although forest area has already declined and is now concentrated in inaccessible locations. Current area under concessions (or Timber License Agreements) has declined since 1970 and has been claimed as part of the success of reforms. However, as a proportion of actual forest cover, logging concessions have increased from 42% in 1970 to 125% in 1987 (based on forest inventories and timber license data of DENR 1988).

The expansion of logging promotes upland farming by reducing the cost of migration and settlement. Two factors normally discourage the colonization of forest lands by upland farmers: their relative inaccessibility and the difficulty of land clearing. Land clearing may require as much as 60% of the total labor associated with upland production. While some studies assert that upland farming is the main cause of deforestation (FAO 1981), the link with logging is important because it reduces the two constraints mentioned above: (*a*) logging roads make forest lands accessible, and (*b*) logging itself reduces the work required to clear the forest.

Once roads are built, most forest lands become effectively open access because neither the timber concessionaires nor the government have the resources to police these lands. The result has been high migration and population growth rates in forest lands. The latest official estimate of detected squatters in the forest zone was about 1 million in 1986 (DENR 1986), when total population was 56 million. This grossly underestimates upland population, implying that only about 2% of the population inhabit more than half of the country's 30 million hectares. In fact, it has been shown with census data that in 1987 close to 18 million, or 30% of the Philippine population, are in the uplands, with 8.5 million occupying forest lands (Cruz, Zosa-Feranil, and Goce; World Bank 1989b).

Aggregate Resource Scarcity and Patterns of Degradation in Nepal

Nepal is extremely poor, with a GDP of $180 per capita in 1988. Only ten countries have a substantially lower per capita gross domestic product (World Bank 1989a). Between 40% and 60% of the population live at levels below the minimum food threshold. Population growth critically affects Nepal's development prospects. Ninety percent of Nepal's workforce are primarily engaged in agriculture, and agricultural land is already fragmented into uneconomic parcels and overused. Thus, the problem

of poverty is one of an aggregate shortage of resources rather than their redistribution.

Current population is about 19 million, with a land area of 13.7 million hectares. The annual growth rate increased from 1.6% in the 1950s to 2.7% in the 1980s. Public efforts to expand agricultural production initially focused on about 1.8 million hectares potentially irrigable with gravity systems, almost 75% of which are in the Terai, Nepal's lowlands. However, constraints to further irrigation development are already substantial, especially in the hills, where most new development will require suitable power to raise water to elevated terraces (World Bank 1990). Water management performance has also been very poor. Less than 30% of the command area actually gets water in the summer and winter, limiting the application of green revolution technology. Thus, between the mid-1970s and the late 1980s, agriculture grew at only 2.4% per year versus the 2.7% population growth rate (World Bank 1990).

Nepal's forests were nationalized in 1957, upsetting centuries of tradition of local control of forest use and shifting the locus of control from the village to the center (Wallace). However, while government assumed legal ownership of forests, it was unable to manage them effectively. Thus, forests became *de facto* open-access resources capable of being privatized if they were cleared. There have been efforts made recently to return the forests to local control, but significant damage has already been done. Population growth, combined with open access, reduced area and quality of the forest and pasture available per household and per livestock unit. Inadequate fodder reduced manure production and application to crops, contributing to stagnating yields. Existing terraces were overworked, and agriculture shifted to more marginal lands in the hills, including areas too steep to support farming without being destabilized.

The result has been significant seasonal and permanent migration to the Kathmandu valley and the Terai. The 1981 census showed that 61% of migrants originated from the hills, and 75% had the Terai as their destination (CBS). Exacerbated by immigration from India, the population of the lowland Terai, originally the most sparsely populated region in the country, grew to 42% of total population, equal to the hills' population (World Bank 1989a).

The Terai represented Nepal's outlet for the overpopulated uplands, but the pace and mode of development mean that the sustainable potential of the Terai is rapidly being used up; forests, soil, and water resources are being depleted or degraded. More than half of holdings are now less than one hectare in size, and 45% are less than half a hectare (IDS). In the hills, 73% of holdings are less than a hectare, with 54% less than half a hectare in size. Nepal's very small farms cannot provide even a poverty line income for the majority of rural families, even if they were to employ state-of-the-art technology. In the absence of significant growth in industrial and service sector employment, most Nepalese will continue to live in poverty.

A Framework for Assessment and Policy

Boserup originally proposed the role of population growth as the stimulus for technical change in agricultural development. Interpreting population growth as the key factor behind long-term changes in relative factor scarcities relates the Boserup hypothesis to models of induced technological innovation (Hayami and Ruttan). According to the induced innovation framework, declining land-labor ratios determine the path of technical change, leading to the mix of technology and new inputs associated with the "green revolution."

In Philippine agriculture, output expanded initially through increases in cultivated area up to the early 1960s. When lowlands that could be easily converted into agriculture were exhausted in the mid-1960s, output expanded through yield increases associated with the green revolution. In contrast, in Nepal the demand to expand agriculture came from the hills. The movement into Nepal's lowlands is relatively recent, following the large-scale eradication of malaria in the 1950s and 1960s and the clearing of much of the Terai forest. Because agricultural research on improving productivity in the hills has produced few results, environmental constraints limited the adoption of high-yielding varieties. Thus, attempts to introduce green revolution technology and to develop irrigation have been largely confined to the Terai.

With population growth and limited employment in lowland agriculture and in industry, the development pattern has gone beyond the green revolution framework. In the Philippines, population pressure has shifted to marginal resources, to forests and uplands for alternative livelihoods. Economic stagnation in the early 1980s exacerbated this process and promoted migration from the lowlands to forest lands. In

Nepal, the upland population continues to expand very rapidly and cannot be absorbed by agriculture in the degraded hills. The impact, therefore, of population on resources has been to force the cultivation of increasingly marginal lands in the hills and to clear and colonize the Terai very rapidly, eliminating much of the Terai forest in the process. For both countries, the result has been continuing poverty for the populations of both the source and destination areas. To comprehend this pattern of limited agricultural development linked to poverty and resource degradation, the problem of population pressure and inappropriate institutions must be explicitly incorporated in the assessment framework.

The framework for policy reform follows this assessment. First, a conventional economic reform effort should remove price and tax current policy biases that lead to overexploitation and inefficient use of resources. Examples include timber underpricing (Repetto and Gillis, World Bank 1989b), and implicit subsidies for extensive or inefficient use of land and water resources (Binswanger, Repetto).

Beyond conventional economic reform, institutional change needs to be considered. Resource management agencies will have to recognize that, given the magnitude of the resource degradation problem, central administration is not appropriate. Management efforts will have to be supported by collective action from communities of resource users. For example, legislation in 1977 officially put much of the control of Nepal's forests under the village panchayats, the local political leaders. But these leaders were not democratically elected, did not represent individual villages, and did not correspond to the user groups who had previously managed the forests as common property. More recently the government has recognized the need for effective local management and is attempting to transfer forest management to direct user groups.

In the Philippines, the government has not made the necessary transition from a regulation- and enforcement-oriented approach to one that focuses on establishing tenure and providing extension support. A social forestry program initiated in the early 1980s allocated long-term use-rights to upland farmers, but coverage is limited to a small fraction of public lands that can sustain agriculture. A more promising effort to change the open-access situation in some areas has been to call for the recognition of ancestral rights for an estimated 6 million indigenous peoples in the uplands (Lynch and Talbott). However, in spite of support from many non-governmental organizations, the bill that would accomplish this is not progressing in the legislature.

Finally, the economic development strategy itself will have to incorporate resource management objectives. Direct focus on reducing population growth is, at best, a long-term proposition. Thus, in the near-term, general economic development strategies will have to carry the burden of reducing population pressure and resource depletion. This will mean added emphasis on employment generation versus industrial policies that promote capital and intermediate input use. In addition, the traditional view of extracting resources to finance development must be supplanted by the recognition that disinvestment in natural capital, unless accompanied by productive investment elsewhere, reduces a country's capacity for sustainable growth.

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Natural Resource Management in the Third World: A Policy and Research Agenda

Jeremy J. Warford and Zeinab Partow

That proper stewardship of natural resources is of central importance to agricultural and economic development has become indisputable. This is especially true for developing countries where natural resource depletion is of immediate economic and social consequence. Poor countries are typically dependent on agrarian and pastoral activities and are thus often most vulnerable to the effects of environmental degradation. This vulnerability results in part from shortages of human and financial capital that severely limit countries' abilities to turn to other economic activities when the resource base can no longer sustain them.

In many developing countries, the combination of poverty, unequal distribution of land and other resources, and population growth is creating incentives for people to overexploit existing resources in order to survive. Exacerbating this is the fact that economic systems do not always contain the automatic self-regulating mechanisms for ensuring the perpetual environmental sustainability of current economic development paths. Under such conditions, it is no longer possible to address systemic problems through piecemeal actions.

Although the dependence of sustainable economic development on sound environmental management is increasingly recognized, to date, economists' attention to the macroeconomic implications of environmental matters has been somewhat fragmentary. The traditional approach to environmental management has been to invest in discrete projects with environmental objectives or to ensure that project components contain elements to mitigate adverse environmental impacts. Although this emphasis on individual projects is important and will undoubtedly continue, it is clearly inadequate alone and should be supplemented by a strategy that integrates environmental and natural resource management directly into economic and social policy. A trend along these lines can already be observed in the recent evolution of policies in development institutions, notably those of the World Bank.

In attempting this integration of environmental issues into the core of economic policy making, a number of central issues for further work arise. This paper will outline some of these issues in an effort to present a series of promising research avenues for the future.

The Valuation of Natural Resources and Cost-Benefit Analysis

Conventional economics has undoubtedly made a significant contribution to the understanding of natural resource issues, yet it is often unable to address a host of emerging concerns. A major limitation of conventional approaches to natural resource economics is their concern with only those resources which directly provide economically valuable productive services, to the exclusion of environmental services such as waste absorption and ecological and life-support mechansims.

In response, alternative views have emerged that see resource depletion and waste generation by the economic system as integral to the whole rather than relegated to the margins under the umbrella term "externalities." By demonstrating the physical dependence of economic activity on the sustainability of crucial natural-resource systems and ecological functions, alternative views seek to highlight the economic costs resulting from the failure to preserve sustainability and environmental quality.

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Nevertheless, a bias against sound environmental management has been encouraged by the difficulty of assessing the monetary values of environmental goods and services. Although the contribution of conventional economics to these challenges has been important in promoting the use of a systematic means of addressing resource allocation decisions, the available analytical means have not been very effective in addressing some of the more intangible services provided by the environment, or in handling specific problems in real-world cost-benefit studies.

The desire to assign monetary values to environmental consequences of project and policies has so far resulted in either trivial exercises in which easily identifiable monetary values are assigned to cost or benefit streams or in the inability to establish adequate criteria for valuation—as has been the case in the failure to place values upon the welfare of future generations or on the extinction of species. The challenge which faces economists is to devise a more comprehensive approach to cost-benefit analysis in which rigorous attention is paid to the nonmonetary consequences of investments.

Although there is a growing recognition that efforts in these areas are important and need to be expanded, cost-benefit analysis and valuation of resources are relatively well-trodden fields with as yet unresolved questions that do not promise substantial advances in knowledge in the near future. More significant improvements in environmental management are likely to result from efforts to integrate environmental concerns into macroeconomic and other government policies.

Macroeconomic Policy

Large-scale development projects are typically subjected to cost-benefit analysis and environmental assessment by concerned public agencies. In contrast, the impacts of the vast number of small-scale individual resource users, each of whom has only a small effect on the environment, can rarely be subjected to analysis at the individual level. The combined consequences of such activities have to be managed at the broader policy level. The individual resource user can be reached effectively only by the use of macrolevel policies and incentive systems such as price policies, subsidies or taxes, or land reform.

No single policy or set of policies is correct or always applicable. Some policies require direct intervention to implement, while others rely on market signals. Indeed, the pendulum, which over the past decades has swung from a position favoring government intervention to one supporting complete reliance on free-market mechanisms, appears now to be in mid-path, with research focusing on providing a balanced prescription between the two extremes. The centrality of macroeconomic policy to environmental management has nevertheless remained clear.

In altering the level or rate of change of economic activity, macroeconomic policy inevitably impacts upon the environment, although often in ways that are unanticipated. Many developing countries, for example, maintain overvalued exchange protection to home market producers. The discrimination against exports in an economy based on agriculture, for example, can be expected to influence the types of crops that are grown. The implications for sustainability may be beneficial or adverse, but they have traditionally not been considered in establishing macroeconomic policies.

Existing studies on the relationship between government policies and environmental management only serve to underline the importance of the linkages. Binswanger and Mahar, in separate studies, describe how massive private investment in the expansion of beef-cattle production in fragile ecological conditions in the Brazilian Amazon has been supported by domestic governments in the form of tax concessions and provision of infrastructure.

The plans to construct 15,000 kilometers of roads in the region have perhaps been the most visible of the government's interventions, not least for the environmental damage they generated. The impact of government fiscal and tax incentives has been perhaps less readily identifiable though not necessarily less dramatic. Some of the most powerful of the incentives have allowed Brazilian corporations to take up to a 50% credit against their federal income tax liabilities under certain conditions, or have provided access to subsidized credit lines for cattle ranching and other activities. Livestock projects approved in this way have probably been the single most important source of deforestation, accounting for up to two-thirds of the deforestation in Amazonia. Not only have these projects been environmentally damaging, but they have largely been unjustified in social cost-benefit terms, although they may have yielded considerable private profits.

Since 1980, the volume of official rural credit has been drastically reduced and the subsidy element was eliminated in mid-1987. The approval of livestock projects in rain forest areas has also been officially prohibited since 1979, but this rule has been difficult to enforce. In the long run, reversal of long-standing policies will surely have beneficial macroeconomic, sectoral, and environmental effects.

Similarly, in Indonesia, Barbier shows how government agricultural pricing and subsidy policies encourage inappropriate land-use and thus contribute to environmental degradation. Rigid import controls and a heavily protected domestic pricing structure may provide indirect disincentives to soil conservation. As the average returns to highly commercialized and input-intensive crops such as vegetables increase, share tenancy and absentee ownership become more common. This can reduce the incentive for long-term investments in improved land management if tenancy arrangements are insecure and if the objective of absentee owners is short-term profit maximization or land speculation. The increased profitability of vegetable crops also encourages farmers to cultivate on steeply sloped volcanic soils, where water run-off, and therefore soil erosion, are greater.

The lack of adequate marketing facilities is another key factor that contributes to environmental degradation and low productivity on marginal uplands in Indonesia. The ability of farmers to undertake improvements and investments in agroforestry and livestock-based systems relies in part on the returns to their marketing efforts. Government policies regarding subsidies to agricultural inputs have resulted in the overuse of fertilizers, particularly in lowland irrigated areas. Fertilizer subsidies may discourage farmers from facing the full economic costs of declining soil fertility and from responding with sound land conservation measures.

In view of the potential environmental impact of policy reforms at the macroeconomic level, one of the major instruments used by the World Bank to address the policy-environment link is policy based, structural, and sectoral adjustment lending. Adjustment lending has recently begun consciously to incorporate measures to protect natural resources and to improve their management. In addition to institutional and economic reforms, adjustment loans contain a number of conditions that may benefit the environment. These include elimination or reduction of subsidies for pesticides, full cost recovery in pricing energy or water services, and improved land distribution policies and tenure arrangements.

It must, however, be added that generalizing about the effect of economic adjustment on the environment is difficult. Policy interventions that have a benign effect in one country may have exactly the opposite effect in another. Reforms such as the elimination or reduction of subsidies or the substitution of cash crops for food crops can result in either positive or negative environmental consequences.

Better understanding is therefore required of the chain of causality leading to severe environmental problems in order that remedial policies can be identified. The difficulties arise because of the complex interactions between natural events and human activities that characterize the environmental problem. To improve its knowledge in this area, the World Bank is investigating the relationships between geographic data, including remote sensing, and various kinds of socioeconomic data. The purpose is to see if recent advances in the processing of geographic information can be used to identify the impact of changes in key economic and social variables in order to improve the basis for policy intervention. Research needs in this area are massive: they include a better understanding of the impact on the various forms of environmental degradation of a range of variables, including fiscal and trade liberalization policies, income distribution and poverty, and population growth.

Awareness of the macroeconomic importance of environmental problems has not been facilitated by the well-known shortcomings of national income accounts. It is increasingly recognized that conventional measures of national income give misleadingly favorable estimates of economic well-being and growth. Prudent accounting of national income should reflect sustainable income as closely as possible. Under the current conventions, however, no account is taken of the reduction in national wealth through the depletion and degradation of natural resources. In addition, expenditures incurred in protecting society against unwanted environmental side effects are counted as income rather than as intermediate expenditures needed to sustain actual income. Growth built on resource depletion is clearly very different from that obtained from productive efforts and may be quite unsustainable. If compensating investment is not made, growth based on such a process is not sustainable and will send false signals to policy makers. The World Bank is conducting a series of country studies in this area to create an

awareness of environmental issues at the macroeconomic level, and equally important, to identify areas where sound policies require more information.

Population, Poverty, and Environment

Ultimately, many of the environmental problems in developing countries harken back to the fundamental issues of income distribution and poverty and include concerns regarding equity within and between generations. While the poor and disadvantaged certainly tend to suffer disproportionately from environmental degradation, and while poverty is an obstacle to bringing about environmental improvement, it is difficult to generalize about the extent to which poverty is itself responsible for environmental problems. Indeed, some of the most pressing environmental problems facing the planet are those that originate in the wealthy countries.

While the link between poverty, population, and degradation of natural resources in many countries is certainly important, the complex factors that make environmental abuse the most logical short-term strategy for people to pursue need to be better understood. Examined as cumulative regional phenomena, deforestation in Haiti and desertification in the Sahel are much more than the result of poverty-stricken people trying to eke out a living. Invariably, deeply rooted political and administrative structures and economic incentives induce the poor, and the not-so-poor, to cut trees or to abuse the earth's soil. Corrupt officials, bureaucracies, inequitable land tenure patterns, or pressures for short-term successes and projects may make reckless use of the land quite rational and often lucrative. Future research faces the challenge of clarifying the linkages between poverty, population, and environmental management and shedding light on the intervening variables in the equation. A clarification of the impact of environmental degradation on equity over time is another promising research avenue.

Avenues for Research and Policy

There continues to be a pressing need, in both industrial and developing countries, to use increasingly scarce natural resources more efficiently. The means of so doing will depend on a vastly improved understanding of the long-term consequences and the underlying causes of environmental degradaton. Increased effort is needed to identify appropriate social, economic, and other policy measures for sound environmental management. Tracing through the chain of causality is important but often difficult—as in the case of unravelling the effects of population and poverty on the environment—and environmental work aimed at developing this understanding is a priority.

The greatest research needs lie in the application of existing knowledge rather than in searching for new concepts and theories. Although additional research in areas such as the valuation of environmental goods and services may be required, deficiencies in information should not be an obstacle to action. There are already economic techniques that make substantial improvements possible to the way in which environmental degradation is handled in economic planning. On the other hand, the difficulty of generalizing about the impact of policies has made the reliance on multidisciplinary, country-specific inquiry a necessity. Multidisciplinary analysis is becoming increasingly important at both the project and the macroeconomic policy levels. In addition to issues well within an economist's range of expertise, such considerations as improved institutional analysis and policy incentives need to be addressed.

Experience shows that good economics is typically good for the environment. There are innumerable opportunities for investments and policy reforms that meet both environmental and economic objectives, and this fact is consistent with the growing evidence that environmental degradation is undermining sustainable development in many countries. However, there will always be important instances in which economic and environmental objectives conflict to some extent. For example, limits may exist to the environmental benefits that can be derived from trade liberalization. Market mechanisms will not cover the full environmental agenda unless they are supplemented by government interventions of various kinds. In particular, the role of "green taxes," possibly substituting taxes on income or capital, should be carefully considered.

Finally, institutional problems in their many forms, including inefficient public agencies, inadequate legislation, and cultural factors are another area of special concern. Research is needed to uncover means of better understanding how local institutional structures help or hinder environmental management and to help in the de-

sign of institutions that respond to local needs.

The range of researchable activities is massive. However, the areas in which knowledge needs to be improved tend to be more empirical than conceptual; the division between environmental research and more policy-oriented or operational work should thus become increasingly blurred. This holds great promise for the applicability and contributions of future research to the resolution of today's pressing environmental problems.

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Arresting Renewable Resource Degradation in the Third World: Discussion

Daniel W. Bromley

The three papers approach the problem of resource degradation from similar angles. Rather than comment upon any one of them in detail, the brief space calls for general comments that would seem to apply to each. I will make four points. First, I will argue that the blame for resource degradation that is laid on population growth is largely misplaced. Second, I will remind the reader that policy reform is precisely the essence of institutional change. Third, I want to emphasize the role of property regimes in natural resource policy. Finally, I will close with a few observations on the relevance of our concepts and maintained hypotheses about development, sustainable development, and wise natural resource use in the tropics.

On Population Growth

Population growth figures prominently in all three papers, as well as in the common perception of important causes of resource degradation. While I certainly do not wish to suggest that population growth is unimportant, it is my view that this issue has been overdone (Bromley 1989b). Blaming population growth allows inept or corrupt governments to shift the blame for their behavior—or their inaction, as the case may be—to promiscuous peasants. It further allows governments to appear helpless in the face of forces beyond their control. And it allows them to attract international assistance for projects to correct certain resource insults, the better to appear more beneficent to their citizenry.

The very essence of the state, and its sole justification one might argue, is to design institutional arrangements to address new contingencies and new scarcities faced by its citizens. To blame the masses, to plead helplessness, and yet to engage in—or to promote—many of the resource-use patterns we observe, is disengenuous at best. Resource policy in the developing world would do well to move beyond the bedroom.

Policy Reform and Institutional Change

The papers variously talk of policy reform and institutional change as if to suggest that these are fundamentally different things. In fact, institutional change, by altering rules, conventions, and entitlements, is the very essence of policy reform. It is institutional arrangements that map (transform) policy pronouncements into choice sets from which individual maximizing agents will select preferred actions (Bromley 1989a). One cannot talk of policy reform without addressing institutional change, and I would have been happier had the three papers been more clear on this.

Property Regimes and Natural Resources

The papers offer welcome relief from the mischief that holds open access regimes (*res nullius*) to be indistinguishable from common property regimes (*res communes*). There are really three general classes of property regimes in natural resource management: (*a*) state property regimes, (*b*) common property regimes (private property for a group), and (*c*) individual property regimes. Open-access regimes, or what has unhappily been confused with common property, is in a class apart from these three property regimes for the simple reason that there are no property rights in open access (Bromley and Cernea). Common property and individual property share the trait that the users (or managers) are also the owners; in state property regimes (such as a national forest), neither the users nor the managers are the owners. Common

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property and state property share the trait that the number of users (or managers) is often large. By definition, group size in individual property regimes is usually thought of as being one. But of course much "individual" private property (personal dwellings and automobiles) is co-owned by spouses.

Given these aspects of property regimes, I suggest that natural resource policy would benefit if we were to pay more attention to the literature focusing on the separation of ownership and control (Cheung, Fama, Grossman and Hart, Jensen and Meckling). In this regard, much of the resource problem in the developing countries arises because national governments have created an ownership structure (state property regimes) without the attendant capacity to control individual user behavior. As a result, many natural resources are characterized as open access available to any and all claimants. It is natural resource management by proclamation, and it does not work.

The Conceptual View

Much natural resource activity in the developing world is still driven by the colonial (and precolonial) view that resources are for extractive purposes to earn revenue for the state. We must begin to recognize that not all national leaders are as interested as we in "development" and wise natural resource use. I note that the recent fascination with "sustainable development" misses the point by asking about the meaning of sustainability while ignoring the meaning of development. Recall that development means change, and that all change threatens some vested interests. However, many governments view their country rather like family-owned firms with the objective of maximizing revenue in Miami, Zurich, or Singapore bank accounts. Improved modeling of natural resource policies awaits the incorporation of this unfortunate objective function into our work. I urge that we not continue with the idealistic view that governments are innocent bystanders in the process of squandering natural capital. Otherwise, our models are behaviorally naive and little progress will occur.

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Arresting Renewable Resource Degradation in the Third World: Discussion

Pierre Crosson

Concern about degradation of renewable resources in developing countries is deep and widespread in the countries themselves, in development agencies such as the World Bank and the U.S. Agency for International Development, in the world environmental community, and among academics interested in economic development. I share this concern. But I note that the evidence of resource degradation on which it is based is fragmentary and anecdotal. Soil erosion is widely believed to be a major threat to agricultural productivity and water quality in the developing countries. The fact is, however, that we have very little reliable information about the amount of soil erosion in these countries and even less about its productivity and water quality effects. Aquifers are being mined in many developing countries and crop productivity is lost to saline and water-logged soils in irrigated areas, but the economic significance of these situations on a country or global scale is obscure. Tropical deforestation is troubling largely because of fears that the associated loss of biological diversity will in time impose high social costs. But with great uncertainty about how much tropical deforestation is occurring, and estimates of the total number of species in the world varying between 4 and 30 million, we have only the vaguest notion of the magnitude of the threat to biological diversity and not a clue as to the social costs of possible losses.

Despite the skimpy information about renewable resource degradation in developing countries, it has become virtually an article of faith among the interested groups and institutions mentioned above that the degradation is severe and demanding strong and quick public action to deal with it. The papers here under discussion reflect this view, and I wish it were not so.

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Southgate, Sanders, and Ehui begin their paper with the assertion that "degradation of renewable natural resources in the developing countries is taking a serious toll," and in various places they use "excessive" to describe, e.g., encroachments of farmland on forests in Amazonia and damage to the environment in that region. Nowhere, however, do the authors attempt to give any sense of the magnitude of the various threats they perceive nor do they provide any standard by which to judge whether damages are "excessive."

Cruz and Gibbs introduce their paper with the statement that "the degradation of renewable resources in the developing world now threatens not only the economic prospects of future generations but the livelihoods of current users as well." Elsewhere they assert that cleared forest lands have been turned to "nonsustainable agricultural uses, causing severe erosion impacts. On-site production potential is reduced, and downstream sedimentation and siltation of waterways and agricultural land is increased." We are given no basis for judging the severity of these impacts, however, nor are we told the meaning of "nonsustainable agricultural uses."

Partow and Warford are less concerned with specific instances of resource degradation than the authors of the other two papers, but their paper reflects the same implicit acceptance of the conventional wisdom that degradation is general and severe throughout the developing world.

My point here is not to deny that natural resource management currently imposes high social costs in many developing countries. Nor is it to argue that the authors of these papers should have produced quantitative evidence for the various damages they identify. My concern, instead, is that if we are to make progress in understanding and dealing with the problems the authors discuss, we must find criteria for distinguishing among the problems according to their

social importance and susceptibility to treatment through public action. Making such distinctions is the essence of analysis aimed at ameliorating conditions of the sort the authors deal with. The conventional wisdom ignores such distinctions. This is understandable where the "wisdom" is used to mobilize political support for action to address problems of resource degradation. But the intellectual effort needed to understand and deal with the problems requires that distinctions be made. I would be happier with the papers presented here if their respective authors had recognized the importance of this point and had devoted some attention to it. What I am asking for is acknowledgement of how little we know about the present and future social costs of renewable resource degradation in the developing countries and some discussion of how we might use the little knowledge we have to devise workable strategies of research and policies for dealing with the problems of degradation. Such material could be fit quite neatly with the real substance of the papers presented here.

Despite these rather negative comments, the papers do, in fact, contain much of real substance. Space precludes a full account, so I emphasize some high points. Both the Southgate, Sanders, and Ehui and Cruz-Gibbs papers make an important point which, in my judgment, generally gets insufficient attention: attempts to eliminate overuse of open-access resources by bringing them under state ownership or privatizing them often flounder because governments lack the administrative capacity to enforce the newly established property rights. Economists—I have been guilty of this myself—routinely prescribe secure property rights as the solution to the open-access problem, taking the security of the rights for granted. But where government administrative capacity is the limiting resource, security is not guaranteed, thus undermining an otherwise promising attack on the open-access problem. Southgate, Sanders, and Ehui and Cruz-Gibbs do valuable service in emphasizing this important point.

That national fiscal, monetary, and foreign trade policies can have unintended, and undesirable, effects on renewable resource management is not a new idea, but too often it gets insufficient attention in discussion of these policies. The Partow-Warford paper thus is on target in featuring the idea and giving examples of adverse resource and environmental effects where it has been ignored.

I come away from a reading of the three papers asking myself, what are the conditions for achieving patterns of renewable resource management in the developing countries which are sustainable in the sense of indefinitely providing adequate income to the people using the resources? None of the papers directly address this question, but they provide some clues to an answer. Southgate, Sanders, and Ehui and Cruz-Gibbs suggest that easing population pressure on the resource base is a necessary, although not sufficient, condition for sustainability in the above sense. Southgate, Sanders, and Ehui imply that research to develop technologies suitable for the soil and water endowments of the developing countries is critical; and Cruz-Gibbs, also by implication, indicate that in extraordinarily land-scarce countries such as Nepal, expansion of off-farm job opportunities is the only way to maintain, or increase, the incomes of those who remain in farming. Finally, all three papers emphasize the too often perverse effects of government policies on incentives of renewable resource managers. The papers make clear that correcting this is much more complex than "getting the prices right," important though that is. Governments must look also to the resource management consequences of fiscal, monetary, and trade policies, and they must contrive institutional reforms to establish and enforce clear property rights in open-access resources. These papers succeed in conveying some of the flavor of this most formidable set of tasks.

International Competitiveness: Usefulness of Cost of Production and Productivity Measures in Evaluation
(B. F. Stanton, Cornell University, presiding)

Cost of Production and Productivity in Analyzing Trade and Competitiveness

Jerry A. Sharples

Agricultural economists for many years have calculated costs of producing agricultural commodities and measures of productivity (output per unit of input). Early research focused on farm management extension needs; then came the data demands of linear programming models of representative farms. More recently, estimates of costs of production have been used for setting price supports. Similar stories of the growth in demand for cost data and productivity measures could be told for Canada, Western Europe, Japan, and other countries.

The growth of agricultural trade and the more recent increase in trade conflicts have generated interest in issues of competitiveness. One set of issues is concerned about basic comparative advantage. Would the home country's agriculture still be competitive if government support were removed at home and abroad? A second set of issues is concerned about how changes at home or abroad in policy, technical efficiency, or input prices would affect international competitiveness.

On the surface, it seems quite appropriate to apply our accumulated research skills and data on costs of production and productivity to these questions of international competitiveness. What we have found from early attempts to do this in agriculture, however, is that the comparisons have not always been very helpful in understanding competitiveness. For evaluating global competitiveness, some revisions of old measurement methods may be required.[1]

The purpose of this session is to improve our measures of agricultural costs and productivity to provide a better understanding of international competitiveness. My purpose is to present several basic concepts of trade and competitiveness that can be used as guides to refine these measures in order to make useful cross-country comparisons. The analysis begins with a simple model that illustrates basic links between measures of costs and competitiveness. The focus is on costs, but some of the implications may be extended to measures of productivity.

International Competitiveness: Basic Concepts

Assume country A and country B are two of many countries that produce and export wheat. To simplify, assume that the two exporting countries do not consume wheat, wheat is a small part of their total economic activity, and there are no transportation charges between countries. Several important concepts relating to cost of production, productivity, trade, and competitiveness can be shown with this simple model.

Let the curves F_A and F_B in figure 1 represent export supply curves, at farmgate prices, for countries A and B, respectively. They represent the quantity that would leave the farm for export at alternative farm prices. Because there is no domestic use, curves F_A and F_B are also domestic supply curves. Let the curves XS_A and XS_B represent excess supply curves at the port of exit from the country. The vertical difference between the XS and F curves represents variable domestic "marketing," costs (e.g., storage, transportation, handling, including any marketing and export taxes or subsidies). The world market in figure 1 clears at price P_W, with country A producing and exporting quantity Q_A and

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[1] For a detailed example of an intercountry comparison of costs of producing cereals, see Stanton. Capalbo and Denny provide a rigorous example of comparisons of aggregate agricultural productivity measures for the U.S. and Canada.

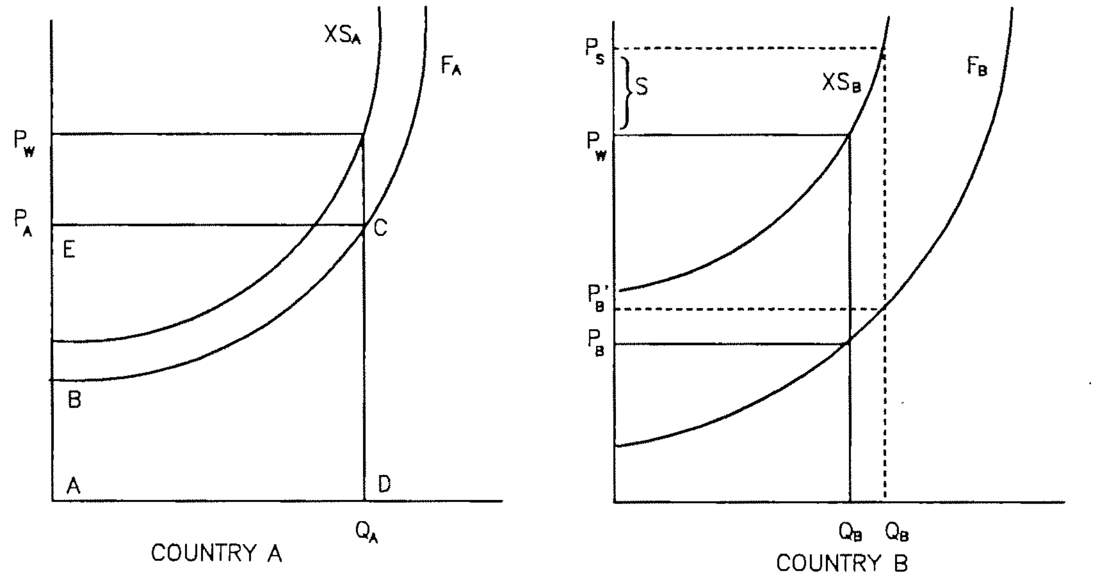

Figure 1. Wheat supply in two countries

country B producing and exporting Q_B.[2] The supply curves show that country A has high variable production costs and low variable marketing costs relative to costs in country B. Thus, the farmgate price in country A, P_A, is higher than the farmgate price in country B, P_B.

Suppose these costs curves were unknown but economists had accurately measured the average cost of producing and marketing wheat in countries A and B. After adjusting for year-to-year variability, they likely would find in country A that the average total unit cost for producing Q_A units was P_A.[3] The average variable production cost per unit would equal area *ABCD* in figure 1 divided by Q_A, and the per-unit residual returns to fixed production factors would equal area *BEC* divided by Q_A. Total marketing costs per unit would equal the difference between P_W and P_A. Equivalent cost estimates could be obtained for country B.

Competitiveness

Concepts of competitiveness may be introduced with this simple model. "Competitiveness" does not have a definition in neoclassical economic theory; it is a political concept. It is becoming conventional, however, for economists and others to perceive of competitivness as the result of the combined effect of market distortions and comparative advantage. For examples, see Amstutz; Barkema, Drabenstott, and Tweeten; and Sharples. "Market distortions" usually implies distortions caused by policy, but it also could include distortions caused by imperfect competition.

Comparative advantage is theoretical, explaining trade and optimal welfare in an undistorted world. Competitiveness, on the other hand, relates to the observable. If firms and industries cannot survive by selling at the going price, they are not competitive. If they are able to survive and increase market share, they have become more competitive. Note, however, that an increase in competitiveness of an industry, possibly the result of government support, does not necessarily imply an increase in national welfare.

In the context of figure 1, a country over time can become more internationally competitive in exporting wheat by doing things that shift its wheat export supply curve right (or down). Examples include (*a*) increasing the stock of fixed resources in wheat production and marketing, (*b*) increasing efficiency (productivity), (*c*) reducing input prices, (*d*) reducing interest rates, (*e*) changing policies to lower taxes or raise subsidies on wheat production and marketing, and (*f*) depreciating the home currency, discussed below.

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[2] This model represents an intermediate-run equilibrium where production and input use respond to price changes that persist for several years. For individual commodities, most inputs would be considered variable. For example, land would be a variable input to production of one crop on a diversified farm. Its opportunity cost would be its return from alternative crops.

[3] These curves represent private costs. Additional social costs of private production and marketing, such as pollution or soil erosion, are not included unless reflected in taxes or other costs imposed on private firms by public policy.

Analyses of the forces listed above help to explain changes in past competitiveness and help to evaluate alternative futures. The rest of the paper addresses how international comparisons of production costs can help to better understand competitiveness.

Cost Estimates and the Supply Curve

In order to address global wheat competitiveness, in the context of figure 1, we need to have (*a*) estimates of the intermediate run wheat supply and export supply curves and (*b*) estimates of how the forces listed above would shift the supply curves. Estimates of costs of production and marketing tell us little about the supply curves, but cost estimates can help to estimate shifts in the supply curves. Cost estimates also provide a more detailed picture of how differing competitive forces uniquely shaped agriculture in different countries at the time the costs were estimated.

Economists generally agree that agriculture is an increasing-cost industry, as represented by the upward-sloping supply curves in figure 1. The supply curve shows the cost of producing the marginal unit over a range of output prices. A cost survey typically provides information on average variable and average fixed costs at one point in time (i.e., for one output price). Thus, an estimate of average unit cost tells little about the supply function.

Furthermore, knowing the distribution of costs across all firms in the industry may not tell much about the supply curve because that distribution does not represent marginal costs. Suppose, based on a survey of costs of all firms, that production is arrayed from lowest variable cost to highest variable cost. This distribution shows how all firms at one point in time react to one set of expected market conditions. The industry supply curve, on the other hand, shows how all firms in the industry would react to a range of alternative expected output prices. Firms would be expected to change their production methods and input mix in response to expected changes in output price.

Getting Cost Comparisons Right

Even though cost estimates do not help much in defining the supply curve, those data are still useful for answering questions about competitiveness. To do this, however, the comparisons must be consistent with trade theory. The remainder of the paper focuses on issues associated with comparing costs across countries.

Suppose economists decide to compare wheat costs in countries A and B. They would face many conceptual and technical problems, problems that are discussed in the other papers in this session. The focus here is on three important issues specifically associated with making international cost comparisons: (*a*) to include marketing costs, (*b*) to include the impacts on costs of taxes and subsidies, and (*c*) to get the exchange rate right. These are discussed below.

Include Marketing Costs

Figure 1 shows that in order to evaluate international competitiveness, marketing costs as well as production costs need to be examined. Comparisons of costs of production tell us little about competitiveness. As presented in figure 1, both wheat exporting countries successfully compete in the global wheat market. It would be misleading to conclude, based only on country B's lower average variable production costs, that country B has a basic competitive advantage in wheat exports relative to country A. In international trade, it is the cost of production plus all the additional costs to get the commodity to the foreign buyer that determine competitiveness.

Account for Public Policy Effects

In order to understand competitiveness, one needs to account for policy measures that influence the price signals faced by producers and marketers. These include input and output taxes or subsidies and border tariffs, taxes, and quotas. For example, suppose country B provides a subsidy on exports of wheat (fig. 1). Although the export price remains at P_W, an export subsidy of S is equivalent to raising the border price to P_S for exporting firms. As a result, producers would receive price $P_{\hat{B}}$ and country B would produce and export quantity $Q_{\hat{B}}$. Because of the higher price and added production, marginal and average variable costs of production and marketing per ton of wheat would increase as shown in figure 1. Land rents and land values would increase because of their larger residual returns. An accurate accounting would show total costs

equal to P_S in country B, while in country A they would equal P_W. The subsidy raised costs.[4] Likewise, removing the subsidy would be expected to lower costs.

Consider Exchange Rates

Comparisons of production and marketing costs among countries inevitably involve using exchange rates to convert costs to a common currency. Recent history shows that exchange rates are among the most volatile parameters in the whole process of estimating and comparing costs.

For example, during the nine-month period between June 1989 and March 1990, the real value of the U.S. dollar dropped over 25% relative to the currencies of other countries who export corn and soybeans (USDA, p. 55). That depreciation of the dollar implies that in nine months the U.S. costs of producing and marketing corn and soybeans dropped over 25% relative to costs of competitors. No change in domestic agriculture likely would ever have such a large impact on intercountry cost comparisons in such a short time. Movements of real exchange rates imply that forces outside of agriculture have a very large impact on short-run and longer-run cost comparisons.

The effect on cost estimates of the volatility of real exchange rates may be reduced by computing an average over several years. This procedure would be consistent with the intermediate-run assumptions generally used for evaluating competitiveness issues.

Usefulness of Cost Comparisons

Assume that wheat costs in countries A and B of our example have been estimated. Appropriate attention has been paid to marketing costs, taxes and subsidies, and the exchange rate. What do we learn about competitiveness from the comparisons? We likely find that when averaged over several years, total costs approximate incentive prices (observed prices plus taxes and subsidies) in each country. Thus, the estimate of total cost, taken alone, is not very useful because price and, by extension, total cost are already known.

Further, intercountry comparisons of costs gives little insight into basic forces of comparative advantage. The cost structure of an export industry such as wheat is shaped by policy distortions as well as by the forces of comparative advantage. A different, unknown, cost structure would emerge in each country if distortions were removed and the market were only subject to forces of comparative advantage.

Knowledge of the components of cost, however, are useful for a better understanding of competitiveness. A comparison of cost components across countries show the net effect on input use and factor payments of the existing forces shaping competitiveness in each country.

Cost components may also be used to approximate shifts in supply curves. For example, suppose that we are interested in evaluating the impact of a 50% increase in pesticide costs (resulting from an environmental tax?) in country A on country A's competitiveness in the world wheat market. By knowing the ratio of pesticide cost to total variable and fixed cost of production and marketing, and assuming that there would be no significant change in the input mix, one has an approximation of how much country A's supply curve and export supply curve would shift left (up). The change in costs could be used to shift a supply curve in a world trade model. Then the impact on world trade and competitiveness could be estimated. Care must be taken, however, in using cost data to evaluate how production or exports might respond to major changes in input or output price ratios. Producers facing a major change in price ratios likely would reorganize production, so a new cost structure would emerge.

Conclusions

International comparisons of estimates of agricultural costs (*a*) need to be consistent with trade theory, (*b*) tell little about comparative advantage, (*c*) are useful for showing how differing competitive market forces within countries have influenced input use and payments to fixed factors, and (*d*) are useful to a limited extent for estimating how future incremental changes in input prices, technical efficiency, and policy might shift agricultural supply curves. Thus, by incorporating basic concepts of trade theory,

[4] ERS estimates of production costs omit direct effects of government programs because the estimates are used for policy purposes. A recent study by Salassi et al. shows that in 1988 the ERS estimate of residual returns to management for U.S. rice production was $-105 per acre if policy effects were excluded, and $49 per acre if included.

analysis of intercountry comparisons of costs and productivity should provide useful information about how domestic competitiveness forces have affected resource use and costs.

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Usefulness and Limitations of COP Estimates for Evaluating International Competitiveness: A Comparison of Canadian and U.S. Wheat

Mary Ahearn, David Culver, and Richard Schoney

With the current negotiations under the General Agreement on Tariffs and Trade (GATT), the potential exists for a reduction in agricultural subsidies and trade barriers. This has led to an increased emphasis on the part of the major exporters of agricultural commodities to understand their relative competitive position in a reformed international trading environment. In addition to the GATT, interest in competitiveness has been heightened in Canada and the United States by the recent bilateral reductions in trade barriers under the Canadian-U.S. Trade Agreement. A number of papers by agricultural economists have compared the cost of production of certain major North American crops with the costs of major competitors (Ortman, Stulp, and Rask; Seecharan; Stanton). These comparisons have often been quoted in the popular press and by farm organizations as a means of illustrating the competitive position of North American farmers. However, there has been very little discussion among agricultural economists on the role of cost-of-production estimates in determining the international competitive position of exporting countries.

This paper examines the usefulness and limitations of cost-of-production estimates in the analysis of international competitiveness. First, the role of cost of production in the concept of competitiveness is discussed. The common uses for which cost-of-production estimates are constructed, the general implications of how those uses might affect estimation methods, and the elements of typical cost-of-production estimates are then discussed. Comparisons of wheat produced in Canada and the United States are used for illustration in the remainder of the paper. We begin the comparison by reviewing the structure of wheat production and the export positions of the two countries. Finally, we compare approaches to estimating costs and cost estimates for two regions and then draw conclusions regarding the usefulness of cost comparisons in the analysis of international competitiveness.

Cost of Production and Competitiveness

There is no general economic theory of competitiveness because it is not strictly an economic term. However, the basic economic trade concept, comparative advantage, is a key element in competitiveness. A country is said to have a comparative advantage in producing a particular agriculture commodity if it has the highest return per unit of fixed resource. The implications of comparative advantage are that each country should produce those commodities for which it has a relatively abundant supply of fixed factors, such as land or labor. The industry marginal costs of production which underlie the industry supply curve, in addition to the costs of delivering the product to the market, then serve as the basis for measuring the comparative advantage concept.

There are two major reasons cost of production estimates as they are commonly constructed and published by countries are not directly applicable in the analysis of competitiveness. First, the implications of comparative advantage con-

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cepts are only applicable under a certain set of assumptions, in this case, when international markets are well-functioning and undistorted by domestic policies. Because international agricultural markets are far from being undistorted, the cost and production relationships underlying comparative advantage are only one of the determinants of a country's competitive position. Domestic agricultural and nonagricultural policies have major impacts on competitiveness. But there are other factors which affect a country's competitive position, as well. These include product quality, costs associated with adding value to the commodity, market niches, exchange rates, and perceived reliability as a trading partner.

The second reason cost of production estimates, as they are commonly reported, are not very useful in the analysis of competitive position is they are reported as average costs per acre or hectare or per unit of output for a spatially defined area. These estimates are the average of costs for firms of varying sizes and with varying technologies at one point in time facing a single output price. As such, they represent the average of single points on each firm's average cost curve. These cost data contrast with the cost data underlying the industry supply curve, the relevant concept; these latter data are the horizontal sum of each firm's marginal cost curve.

Uses of Cost of Production Estimates

Cost of production estimates are generally constructed with a single or multiple end-uses in mind which affect how they are measured. Use in analysis of international competitive positions is rarely one of the primary purposes for constructing the estimates. There are three common purposes of commodity cost estimates: as financial planning tools for producers, as policy and program instruments, and for economic analysis of production decisions.

Extension Guidelines

One of the most common uses of commodity cost of production (COP) estimates is as production guidelines published by university and provincial extension agencies. These guidelines are intended to be used by farm operators for planning their enterprise mix and their cash flow position for the coming production cycle. They are frequently referred to as "budgets" because of this forward-looking aspect. In addition, they are oftentimes based on the assumption of best management practices and then viewed as goals to be achieved during the upcoming year. Accordingly, management practices are often formulated by production specialists and are not based on actual farm usage data.

Domestic Program Instruments

The United States has income and price support programs for wheat, feed grains (corn, sorghum, barley, oats), cotton, and rice. Under income support programs, the government makes deficiency payments to eligible farmers and share landlords based on established target prices. Under price support programs, the government offers eligible producers the right to place their commodities in a nonrecourse loan program with an established loan rate. Currently, cost of production estimates are not used directly to set income supports for any commodities. They are, however, used in the setting of price supports for sugar, tobacco, and peanuts. Under the current legislation, cost of production estimates are to be used to set loan rates and target prices for wheat if a wheat-marketing quota is established. Because no such quota has been established, cost of production estimates have not been used to set wheat support levels.

In the past, cost-of-production estimates made by the U.S. Department of Agriculture's (USDA) Economic Research Service were used in setting U.S. target prices for wheat, corn, cotton, and rice under the 1977 farm bill. That provision was later removed with the 1981 and subsequent bills. Nevertheless, cost-of-production estimates are still reviewed and discussed in the political arena. Commodity interest groups show continued interest in the levels of the cost-of-production estimates because they believe that, even if they are not used by law to set target prices, policy makers likely use the estimates as guidelines for support levels.

By law, the USDA is mandated to produce estimates of the national weighted average of the costs of producing major commodities. This mandate directly influences the concept and estimation methods used to construct the USDA estimates. In particular, the policy use of the USDA estimates has led to efforts to provide cost estimates which are based on the actual, historical costs of a statistically representative group of the nation's producers. It has also meant

that estimates are constructed which exclude the direct effects of commodity programs.[1] Most important, this translates into excluding the returns from the programs on the gross returns side and valuing production shares paid to share rent landlords at market prices, rather than target prices, on the gross expense side. Eliminating the indirect effects of the programs on other components of costs and returns is virtually impossible.

In Canada, two major ongoing programs have been used to stablilize the incomes of wheat producers: the Western Grain Stabilization Act (WGSA) for the Prairie region and the Agricultural Stabilization Act (ASA) for the other wheat regions. Under the WGSA, producers pay a premium to participate in the program. The WGSA guarantees net cash flow at 100% of the previous five-year average level. The net cash flow estimates are based on the whole-farm National Farm Survey undertaken by Statistics Canada. Individual producers participating in the program are able to enroll up to $60,000 worth of grain in the WGSA each year.

Under the ASA, all wheat producers are eligible for payments if a pay-out is triggered. The pay-out is triggered if wheat price is below 90% of the previous five-year average wheat price with adjustments based on changes in the cash cost of producing wheat. Although the Canadian government does not have an official program for estimating costs of production on an annual basis, cost-of-production data are collected when needed to administer the ASA program. In addition, several universities and provincial governments estimate the costs and returns associated with commodities of importance in their areas.

Economic Analysis

Although they are usually not constructed for the primary purpose of conducting purely economic inquiries, cost-of-production estimates are used in a variety of economic analyses. Of special interest in this paper is evaluating comparative advantage and competitiveness, but other examples abound, for example, economies-of-size analysis. Estimates of long-run costs of production are generally the most useful for economic analysis. In particular, these estimates include a complete costing for all inputs, including owned inputs which are valued at an opportunity cost.

Problems in Comparing Cost-of-Production Estimates from Multiple Sources

Ideally, commodity cost and return data that are being compared should be generated under identical procedures. This is rarely the case in practice if the estimates are not of the same source because commodity cost estimation is not a straightforward accounting operation, in contrast to whole-farm accounting. Operators generally do not keep their records on a commodity-by-commodity basis, and if they do, they are forced to make some simplifying assumptions about allocating some costs.

No matter what the purpose of comparison, secondary users of cost and returns estimates from multiple sources need to consider the variation in assumptions and approaches across sources. Much of the variation results from the different primary end uses described above. Other differences are simply the result of a value judgment on the part of an economist on how best to construct an estimate given production theory and the resource constraints. This is especially an issue for the imputed returns to owned inputs. Economic theory provides the guide that an opportunity cost should be measured, but a great deal of variation exists in the assumptions involved in specifying and then measuring the appropriate rate of return to inputs. Moreover, imputed costs are generally not a small component of total economic costs. The most straightforward costs to allocate among commodity enterprises are the cash variable costs. In 1988, cash variable costs among the major field crops varied from 30% to 60% of total economic costs (USDA). Furthermore, even some of the cash variable expenses, such as fuel, lube, and repairs, are based on the actual acres covered by specific machines as reported by operators, in conjunction with the use of some assumed engineering relationships. Klemme, Schoney, and Finner found, through a comparison of farmers' estimates of the total time spent in machine use for all farm enterprises with the sum of estimated machine use as generated by typical cost of production estimation techniques, that standard procedures underestimated machine use and, hence, machine-related costs.

The potential for variation in estimates from multiple sources resulting from differences in

[1] The 1990 farm bill has specified that the direct effects of commodity programs are to be included in cost and return estimates.

estimation methods, rather than actual cost levels, is too extensive to elaborate in this paper. However, a data user should consider the following set of questions regarding consistency in measurement approaches when comparing cost and return estimates from multiple sources: What cost concept is being measured, for example, a net cash flow or an economic cost? Are the underlying data representative of the population of interest? Are the estimates intended to be a reflection of actual costs or of best-management costs? Do the cost estimates include landlord as well as operator costs? How often are the production technology data collected; are they for the year in which comparisons are being made? How are the effects of government policies treated? What portion of costs are out-of-pocket costs and what portion are imputed? What are the imputation procedures? Is a "budget-generator" used with implicit engineering relationships, or are operators asked to allocate all their costs among the commodity enterprises? Is depreciation measured on a replacement basis or an historical basis? How are shared inputs of multioutput firms allocated, for example, machinery costs? How are cash fixed costs allocated, for example, interest charges? Are real or nominal interest rates used to impute returns to capital?

Wheat Production and Exports in North America

Wheat is an important crop for both the United States and Canada. In terms of value of crop receipts, it is the most important crop grown in Canada and the fourth most important crop grown in the United States. The 1986 Canadian Census of Agriculture reported that 119,718 farms produced wheat, representing 40.8% of all census farms. Saskatchewan is the largest Canadian wheat producing province with 55,202 farms producing wheat. In the United States, 352,237 farms produced wheat in 1987 according to the U.S. Census of Agriculture; these farms represented 17% of all U.S. farms. North Dakota, Kansas, and Oklahoma are the top three wheat-producing states and account for approximately 30% of U.S. production. Wheat-producing farms are more specialized in Canada than in the United States. Specialized wheat farms (50% or more of farm sales from wheat) accounted for 18% of the farms producing wheat in the United States and 40% in Canada. Small farms with farm revenues of less than $50,000 account for approximately 50% of the farms growing wheat in both United States and Canada, but only about one-quarter of the wheat acres. More than half of the wheat acres in each country, however, were on farms with revenue of between $50,000 and $250,000.

Compared to most other agricultural commodities, wheat is not a homogenous commodity. There are five major classes of wheat, each with different final uses which affect demand on the international market. Hard Red Spring Wheat (HRSW) is the dominant wheat crop grown in Canada, accounting for 77% of the Census acres in 1986. High protein wheats in the United States are less dominant than in Canada. In the United States, HRSW accounts for approximately 20% of U.S. production; and hard red winter wheat, with a somewhat lower protein level, accounts for about half of production. The United States also produces and exports wheat in the other three classes: soft red winter, white, and durum wheat.

The United States and Canada compete in the world market for sales of wheat with similar characteristics. In the United States, over half of the wheat crop is exported, accounting for some 30%–40% of the world wheat trade. Over three-quarters of the Canadian wheat crop is exported giving Canada a 15%–20% share of the world wheat trade.

Comparison of Saskatchewan and Northern Plains

We will compare estimates of wheat production costs for two similar regions in the United States and Canada for 1987 and 1988 to illustrate the issues regarding comparability of approaches. We view this comparison as one based on as close to a consistent approach as an international trade analyst could realistically expect to find in today's agricultural data system. For this reason, and because environmental growing conditions are very similar, we would a priori expect cost estimates to be very similar.

The U.S. estimates are for all classes of wheat in the Northern Plains region, which includes Minnesota, Montana, North Dakota, and South Dakota (USDA). The USDA estimates use three general approaches to estimating costs: wheat production costs are reported by the operator, wheat input quantities are reported by the operator and valued at a state average price, and input costs are estimated with a budget generator system. The budget generator system is used to estimate machinery-related costs and relies on

operators' reports of actual machinery used and times over or hours of use in conjunction with established engineering relationships of machine efficiency (USDA). USDA collects data on production technology every four to five years and updates quantities of output and prices of inputs every year. The production technology underlying the estimates for 1987 and 1988 reported here are based on the 1986 wheat version of the Farm Costs and Returns Survey. The wheat survey is designed to be representative of all wheat production in the region and has a sample size of 255 farms which represent approximately 55,000 wheat-producing farms.

The Canadian estimates are based on Top Management Workshops data for Saskatchewan (Schoney). The Saskatchewan workshops require a high level of time input from participants and are not based on a representative sample of farms. Because large, possibly more efficient, farms are overrepresented in the sample, one might expect to find costs lower for Saskatchewan than those for the neighboring U.S. Northern Plains region, whose costs are based on a representative sample of all wheat producers. However, it is unlikely that the lack of representativeness of the Saskatchewan sample would have a large impact on the average cost level because small farms account for a disproportionately small share of wheat acres and wheat production.[2] The Saskatchewan sample size was 78 farms for 1987 and 115 farms in 1988. The general procedures are similar to the USDA system with two exceptions: (*a*) complete data, including data on underlying production technologies, are available every year and (*b*) because cost data are collected on every enterprise on the farming operation, the system has a built-in check to ensure that the sum of enterprise costs as estimated by standard procedures does not exceed the whole-farm costs.

The methods that are used to calculate the various cash cost items from the USDA and University of Saskatchewan are summarized in table 1 and provided in detail in Schoney and USDA. The methods of calculating cash costs are generally similar. Not surprisingly, methods to estimate fixed cash costs and imputations for owned inputs between the two systems do differ. For example, returns to nonoperating capital under the USDA system are based on a real rate of interest and are based on a nominal rate of interest under the University of Saskatchewan system.

[2] A comparison of farms participating in a similar, nonrepresentative farm-record-keeping system in North Dakota to a representative sample of farms found that the characteristics of farms were significantly different between the two groups (Gustafson, Neilson, and Morehart).

Results and Discussion

The wheat cost and return estimates for Saskatchewan and the U.S. Northern Plains are reported in table 2 for 1987 and 1988. In 1987, growing conditions were relatively normal, but both areas experienced a severe drought in 1988. The yields on average and total revenue (excluding government payments) were very similar in Saskatchewan and the U.S. Northern Plains.

In terms of variable cash expenses per acre, wheat production costs were also similar. In 1987, variable cash costs in the U.S. Northern Plains were $36.23, compared to Saskatchewan's $33.43. Although the sum of variable cash costs were similar, significant differences exist for individual expense items. For example, chemical expenses are higher in Saskatchewan, whereas fertilizer expenses are higher in the Northern Plains. Because of the relative consistency in estimation methods between the two systems for these inputs, we can confidently assume cost differences are real and draw relevant conclusions. For example, policy reforms or new technologies which may affect chemical quantities applied and/or price would probably have relatively more impact on Saskatchewan producers than producers in the Northern Plains.

Fixed cash costs per acre were similar between the two regions in 1987 but much less so in 1988. The $2.54 difference widened to $4.76 in 1988. This can be explained only by the methods. USDA allocates fixed cash costs based on the proportion wheat value of production is to total value of production versus the University of Saskatchewan's approach of allocating fixed cash costs based on the proportion cash variable wheat costs are of total farm cash variable costs. With the extreme drought conditions of 1988, total value of production was down and, moreover, wheat was more adversely affected than other commodities produced on farms in the region.

Estimates of capital replacement and returns to operating and nonoperating capital are all significantly different between the two regions in both years. However, so are the estimation methods used to calculate them. The important point for purposes of this paper is not how the

Table 1. Comparison between USDA and University of Saskatchewan Methods of Calculation

Cash Expenses	USDA	University of Saskatchewan
Seed	Multiplies farmer-reported seeding quantities by state average seed prices.	Multiplies farmer-reported seeding quantities and prices.
Fertilizer	Multiplies state average prices per pound of primary nutrients by farmer-reported pounds of nutrients applied.	Multiplies farmer-reported price of fertilizer by quantities applied per acre.
Chemicals	Producers report their chemical expenses for a particular crop.	Multiplies quantities of individual chemicals applied by farmer-reported price of the pesticide.
Custom Operations	Producers report custom operation expenses for a particular crop.	Same as USDA.
Fuel, lube, and electric	Producers report data on machine size, age, and acres covered. These data are combined with engineering specifications of speed and field efficiency to arrive at hours per acre. The hours per acre are multiplied by fuel consumption per hour and fuel price to determine fuel expense per acre. Lubrication costs are calculated at 15% of fuel expenses. Electricity for irrigation is estimated from farmers' reported equipment specifications and hours that water is pumped.	Same as USDA except for pick-up trucks, except a calibration procedure is used to ensure that individual commodity estimates for all commodities produced equals the whole-farm estimate. For pick-up trucks, costs are included as general overhead.
Repairs	A repair rate per machine is calculated based on engineering relationships for each machine which is divided by the number of hours the machine is used on a particular crop.	Same as USDA except for pick-up trucks, except a calibration procedure is used to ensure that individual commodity estimates for all commodities produced equals the whole-farm estimate. For pick-up trucks, costs are included as general overhead.
Hired labor	First, total hours of both unpaid and paid labor are calculated. Hours of machine-related labor requirements are estimated based on reported field operations. Hours of hand labor requirements are estimated based on the type of irrigation system and the hours water is pumped plus the hours of other hand labor reported by farmers for other purposes. Total hours are then designated as paid or unpaid based on the proportion of labor paid a cash wage on all crop farms. Estimated paid hours are then multiplied by the state wage rate for farm labor to give the hired labor expense.	Hired labor expenses are the sum of paid machine-related labor hours and expenses for salaried labor. Hours of machine-related labor are calculated in a manner similar to the USDA procedure. Salaried labor expenses are allocated to the commodity based on the proportion cash variable expenses of the commodity are all cash variable expenses. Salaried paid to spouses are excluded.
Technical services, other	Costs reported by farmers for such items as soil testing, scouting and land surveying.	Same as USDA, except it also includes crop insurance premiums.
General farm overhead	Farm overhead is the sum of non-crop-specific activities, such as utilities and blanket insurance policies. Overhead costs are allocated to the commodity based on the proportion value of production of the commodity is of total farm value of production.	Overhead costs include items similar to the USDA. Overhead costs are allocated to the commodity based on the proportion cash variable expenses of the commodity are of all cash variable expenses.
Taxes and insurance	Taxes equal the sum of personal property tax for machinery plus real estate taxes. Insurance charges for machinery are also included.	Real estate taxes paid are included, but all insurance costs are included in general overhead.
Interest	Data on actual operating and real estate interest paid are collected annually and allocated to the commodity in a similar fashion to general farm overhead.	Interest expenses are the commodity's share of charges actually paid for operating, machinery, and real estate loans. Interest on operating loans are allocated to the commodity based on the proportion of cash variable expenses. Machinery and real estate interest expenses are allocated to the commodity based on the proportion of the value of the machinery and land used for the

Table 1. Continued

Cash Expenses	USDA	University of Saskatchewan
		production of the commodity of the whole farm value of machinery and land.
Capital replacement	Based on a per-hour rate that each piece of depreciable equipment is used and on the hours per acre that each is used in the production process. Hourly capital replacement is calculated based on the current purchase price less salvage value divided by the hours used.	Based on the nominal loss in value of machines, equipment, and buildings between the beginning and ending of the period.
Charge to operating capital	Calculated based on the product of the value of cash variable expenses and the time between their use and harvest as a proportion of a year and the average interest rate on 6-month Treasury bills.	Calculated as the product of cash variable expenses and a 6% interest rate.
Charge to other nonland capital	Calculated based on the product of the current value of machinery and equipment used for the commodity by the real rate of return to agricultural assets over the previous 10-year period.	Calculated as the product of the beginning investment value of machines, equipment and buildings and a nominal 12% rate of interest.
Net land return	The rental rate is a composite rate based on cash rental rates and the value of share rental agreements. The production under share agreements is valued at the market price. All land, whether owned or rented, is charged a return.	Calculated as a blended charge of cash rent paid, the value of share rents, and an imputed charge for owned land. The charge for owned land is equal to the beginning value of land times 5% interest rate.
Unpaid labor	Calculated as the product of unpaid labor hours times the state average wage rate for hired labor. See hired labor for a description of how hours of unpaid labor are calculated.	Calculated as the product of unpaid hours and a wage rate of $7 (CAN). See hired labor for a description of how hours of unpaid labor are calculated.

Table 2. Economic Costs of Producing Wheat, Northern Plains and Saskatchewan, 1987–88

	U.S. Northern Plains		Saskatchewan	
Item	1987	1988	1987	1988
	($US/Acre)			
Gross value of production				
Primary crop	75.46	48.66	75.61	48.99
Secondary crop	1.55	1.23		
Total	77.01	49.89	75.61	48.99
Cash expenses				
Seed	5.82	6.38	4.05	3.39
Fertilizer	9.58	10.87	8.72	6.44
Chemicals	4.39	4.39	7.56	6.14
Custom operations	3.54	3.18	0.40	0.33
Fuel, lube, & electricity	5.10	4.47	4.74	3.71
Repairs	5.83	5.17	5.14	4.59
Hired labor	1.93	1.72	0.03	0.09
Technical services/other	0.04	0.04	2.79	2.79
Total, variable cash expense	36.23	36.22	33.43	27.48
General farm overhead	6.24	3.77	7.16	8.10
Taxes and insurance	7.43	6.76	2.31	2.33
Interest on operating loans	3.37	1.98	3.42	2.91
Interest on real estate	7.69	3.76	9.30	7.69
Total, fixed cash expenses	24.73	16.27	22.19	21.03
Total, cash expenses	60.96	52.49	55.62	48.51
Value of production less cash expense	16.05	−2.60	19.98	0.50

Table 2. Continued

	U.S. Northern Plains		Saskatchewan	
Item	1987	1988	1987	1988
	($US/Acre)			
Capital replacement charge	21.79	19.74	13.77	11.04
Value of production less cash expense and capital replacement	−5.74	−22.34	−6.21	−10.54
Economic costs:				
Variable cash expenses	36.23	36.22	33.43	27.46
General farm overhead	6.24	3.77	7.16	8.10
Taxes and insurance	7.43	6.76	2.31	2.33
Capital replacement	21.79	19.74	13.77	11.04
Allocated charges to owned inputs:				
Charge to operating capital	0.61	0.74	4.85	3.00
Charge to other nonland capital	4.48	4.43	14.41	10.59
Net land return	28.10	24.77	23.69	21.25
Unpaid labor	4.29	3.84	4.43	3.15
Total, economic costs	109.17	100.27	104.05	86.92
Residual returns to management and risk	−32.16	−50.38	−28.45	−38.03
Price (dollars/bu.)	2.45	3.87	2.58	3.62
Yield (bu./planted acre)	30.8	12.6	29.3	13.5
Economic costs per bu.	3.54	7.98	3.55	6.44

Note: Excludes the direct effects of direct government payment for the United States. Canada/U.S. exchange rate = 0.823 (1987) and 0.758 (1988).

procedures are different and which approach might be preferred, but that they are different and may, in fact, be responsible for the different levels of cost reported by the two sources. Methods for estimating costs of land are similar, however, and based on information on rental markets for wheat land. Again, we find that cost levels in the two regions are comparable when methods are similar.

Costs of production vary considerably across individual farms (Ahearn et al.). The analysis of cost of production throughout the range of cost levels can be useful for analysis of competitive position in two ways. First, the assessment can provide an indication of various quantities which could be supplied at certain levels at least in a shorter-run period. In the longer run, firms, could be expected to adjust to relative price changes and the cost curve may have a different shape. Second, assessment of cost variability can be useful in identifying the reasons certain producers are high cost producers and lead to the development of extension programs or policies to improve per unit of output cost levels. Of course, this type of analysis is fraught with the same limitations as are the average cost esti-

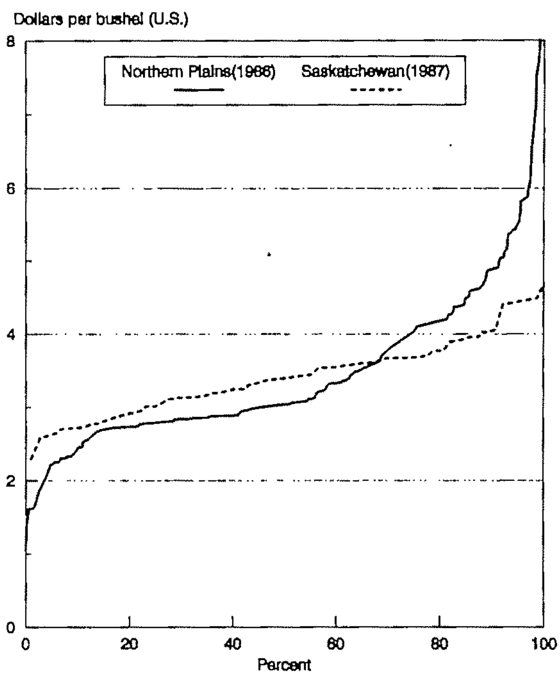

Figure 1. Cumulative distribution of economic production costs for wheat

mates if the underlying estimation methods are incomparable.

Figure 1 shows the cumulative probability distribution of wheat production costs per bushel in Saskatchewan and the U.S. Northern Plains. Two relevant observations can be made about cost distribution information. First, the distributions are quite similar except at the high cost end of the distribution. This is likely because of the low representation of small, generally high-cost producers who account for a small share of the production in the Saskatchewan sample. Second, the average economic cost of production for wheat in Saskatchewan was $4.31 (CAN) and the median was $4.19 (CAN). In 1988, with the severe drought conditions, the difference between the average and median was much greater. Average economic costs for Saskatchewan wheat were $8.51 (CAN) and the median was $6.41 (CAN). This illustrates the importance of analyzing the full range of cost estimates.

Conclusions

The purpose of this paper has been to explore the usefulness of cost of production estimates in the discussion of international competitiveness. Cost-of-production estimates can not be directly used to measure a country's competitive position. However, cost estimates are extremely useful and perhaps a country's leading indicator of competitiveness. In addition, this paper sought to establish that knowledge of the underlying estimation system is critical for evaluating whether comparative costs are real or a result of the estimation system. The most consistency in estimation methods was found to be in the estimation of cash variable costs. This is not surprising, given that these are also the costs that are most easily reported by farm operators.

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International Comparisons of Agricultural Productivity: Development and Usefulness

Susan M. Capalbo, V. Eldon Ball, and Michael G. S. Denny

The simultaneous developments in duality theory, in the use of flexible functional forms in economic research, and in the theoretical linkages between index numbers and production technologies have augmented the tools to address productivity measurement.[1] As a result there have been many studies of agricultural productivity growth in the United States and other countries in the past two decades; international comparisons, however, have received considerably less attention.[2] While from a methodological point of view there is no reason to distinguish intertemporal from international productivity comparisons, the latter comparisons involve additional data-related problems. First, reliable information from many countries may be difficult to obtain. Second, each country's data must be measured in the same units. Third, comparability of input and output groups is needed. These groups are often less comparable among countries than over time within one country.

In this paper we provide an overview and critique of methods for comparing agricultural productivity and efficiency among countries that integrate economic production theory with empirical practices and discuss the relationship of these measures to competitiveness. We conclude by relating the methodological needs to ongoing efforts to construct an internationally consistent data set.

Framework for Productivity Analysis

Productivity research encompasses analysis of both changes in rates of growth and changes in levels. In theory, the distinction between growth rates and levels is trivial since one may be derived from the other. In practice, the uses have been quite different. Productivity growth is used as an indicator of how much more output can be obtained from a given set of resources by a given production unit, i.e., a firm, sector, or country. It is often used with time-series data. Productivity levels are often used to compare different production units at a point in time.

Measures of productivity are related to the production technology. They all involve a comparison of the output level produced relative to the inputs used. Output-based indexes measure productivity differences as differences in maximum output conditional on a given level of inputs; input-based indexes define productivity differences as differences in minimum input requirements conditional on a given level of output. Specific productivity indexes imply some assumptions about the underlying production technology.[3] Indexes that use only an incomplete list of inputs or measure output as value-added can be interpreted as implying restrictions on the technology in the latter case (Capalbo and Denny) and implicit assumptions about the role of other inputs in the former case.

There are two basic approaches to productivity measurement: parametric or statistical procedures and accounting or index number meth-

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[1] Antle and Capalbo review topics in modern production theory that relate to the productivity literature.

[2] Capalbo and Vo provide a review of intertemporal productivity rates for the U.S.; Nadiri and Kravis have produced surveys of international comparisons of productivity; Hoque et al. have synthesized the empirical research on international agricultural productivity. Other research includes the FAO report and papers by Behrens and DeHaen, Hayami and Ruttan, Yamada and Ruttan, and Nguyen.

[3] The Laspeyres indexing procedure implies a Leontief production function; the geometric index implies a Cobb-Douglas production technology; the Tornqvist index implies a homogenous translog production function.

ods. Parametric procedures rely on the estimation of the production technology. To illustrate, suppose the production function for each sector is known or can be estimated: $Y_i = f_i(k,l)$ where i indexes the sector, y denotes output, and k and l denote capital and labor, respectively. Select any input bundle (k_0, l_0) and calculate $y_{i0} = (f_i(k_0, l_0))$ for all countries. The sector in a particular country i will be more efficient than in country j if $y_{i0} > y_{j0}$. The proportional difference in output levels between any two sectors may be defined as the relative efficiency level, and an index can be constructed by defining a base sector. In general, the comparative ranking is not independent of the choice of the input bundle (k_0, l_0). This is desirable since it allows some countries to be more efficient than others for some input bundles and not for others. Otherwise, country i's production function would need to lie everywhere above country j's.

To use cost functions for comparing efficiency, a similar procedure is employed. Assuming that the cost functions, $g_i(w_k, w_l, y)$ for each country are known, choose a particular set of input prices, w, and output level, y, and calculate $c_{i0} = g_i(w_{k0}, w_{l0}, y)$ for each country. The lowest cost sector is the most efficient. The remarks made with respect to the nonuniqueness of the ranking to choice of the input bundle also pertain here to the choice of the input prices and output level.

If the data needed to estimate production or cost functions are available, making productivity comparisons utilizing the parametric methodology is straightforward. However, because all of the required information is rarely available, an alternative procedure for making productivity comparisons utilizes accounting methods which extract a measure of relative efficiency without knowing the complete production technology. The economic rationale for using the accounting approach to measure productivity differences among countries or sectors is found in a series of papers by Caves, Christensen, and Diewert (CCD) (1982a, b), and Denny and Fuss (DF) (1983a, b). These papers are, in part, a response to justify the methodology used by Jorgenson and Nishimizu to compare U.S. and Japanese aggregate productivity levels.

The preferred accounting method assumes that the production technology can be approximated by a second-order function.[4] In particular, a second-order approximation in the logarithms of the outputs and inputs will be used for the production function, and in the logarithms of the input prices, output levels and cost for the cost function. The second-order approximation assumption is utilized for several reasons: data limitations are likely to make higher-order approximations infeasible, and more important, use of a quadratic function as the second-order approximation allows direct linkage to the economic measures of productivity and efficiency. If the production function can be approximated by a quadratic function, then the use of Diewert's quadratic lemma implies that the difference in the logarithm of output between two sectors can be expressed exactly as a weighted sum of the differences in the logarithms of the inputs and a term which can be interpreted as the difference in the productivity level between countries.

To illustrate, let the logarithm of the production function $y_i = f_i(k, l)$ be approximated by a quadratic function in the logarithms of the input levels and a variable d which indexes the country, $\log y_i = f(\log k, \log l, d)$. This specification assumes that the production function in each country has some common elements, since f_i is replaced with f; the presence of d allows the zero and first-order terms in the function to differ. To analyze the differences in the level of output in countries i and j, we can apply Diewert's quadratic lemma to obtain

$$(1) \quad \log y_i - \log y_j = \frac{1}{2}(f_d^i + f_d^j)(d^i - d^j) + \frac{1}{2}(f_k^i + f_k^j)(\log k_i - \log k_j) + \frac{1}{2}(f_l^i + f_l^j)(\log l_i - \log l_j)$$

where f_z^i is the partial derivative of the production function with respect to the zth argument evaluated at the ith country's input vector.[5] The output differential in (1) is caused by a spatial (country) effect and an input effect.

Equation (1) states that the difference in the value of the production function can be evaluated only if the first-order derivatives and the data point are known. Using the assumptions of constant returns to scale and competitive markets, the first-order derivatives are the shares of

[4] An alternative accounting method is the axiomatic approach to index numbers (see Diewert 1986).

[5] Denny and Fuss (1983c) provide for a generalization of the quadratic lemma to the case of discrete variables.

the inputs in total cost and (1) can be rewritten as

$$\text{(2)}\quad \log y_i - \log y_j = \theta_{ij} + \frac{1}{2}[s_k^i + s_k^j][\log k_i - \log k_j] + \frac{1}{2}[s_l^i + s_l^j][\log l_i - \log l_j],$$

where s_h^i is the cost share of input h in country i; and θ_{ij} denotes the spatial effect.[6] Solving (2) for θ_{ij} yields an equation which can be used to measure the differences in productivity levels. The expression θ_{ij}, which is the Tornqvist approximation to the divisia index, can be interpreted as the output level in country i relative to that in country j after accounting for differences in the levels of inputs used by the two sectors. It is, in essence, the geometric average of two unobservable measures: how much output sector j would produce relative to sector i at j's observed input levels and at sector i's observed input levels.

Using duality results, θ_{ij} can also be interpreted in an approximate sense as a measure of relative cost efficiency. The methodology parallels the previous discussion for the production function. Let the cost function $C_i = g_i(w_k, w_r, y)$ be approximated by a quadratic function in the logarithms of input prices and output, and d, $\log C_i = g(\log w_k^i, \log w_l^i, y_i, d)$. Applying Diewert's quadratic lemma we obtain an expression similar to (1), which indicates that the cost differential can be broken down into a spatial effect, an input price effect, and an output effect. Constant returns to scale and perfect competition imply that the cost differential can be expressed as

$$\text{(3)}\quad \log C_i - \log C_j = \rho_{ij} - (\log y_i - \log y_j) - \frac{1}{2}(s_k^i + s_k^j)(\log w_k^i - \log w_k^j) - \frac{1}{2}(s_l^i + s_l^j)(\log w_l^i - \log w_l^j),$$

where s denotes cost shares, and ρ_{ij} is defined as the cost efficiency differences between i and j.[7] Using (3), the Tornqvist approximation to the divisia index of cost efficiency between countries i and j is given by

$$\text{(4)}\quad \rho_{ij} = (\log C_i - \log C_j) - (\log y_i - \log y_j) - \frac{1}{2}(s_k^i + s_k^j)(\log w_k^i - \log w_k^j) - \frac{1}{2}(s_l^i + s_l^j)(\log w_l^i - \log w_l^j).$$

Using (4) and (2), DF show that the Tornqvist approximations to the index of relative productivity differences and to the index of cost efficiency differences are equal (in absolute value) except for a term which is of "second-order of smallness," i.e., $\rho_{ij} \approx -\theta_{ij}$.[8]

The CCD papers convey a similar message: under constant returns to scale, the geometric mean of two Malmquist productivity indexes is equivalent to the Tornqvist productivity index, which can be computed using information on prices and quantities only.[9] Furthermore, under decreasing returns to scale one can use observed data on cost and revenue to adjust the Tornqvist productivity index to reflect the scale effect (see theorems 3 and 4 in CCD 1982a).

Limitations and Usefulness

The comments in this section pertain primarily to the index number approach to productivity level comparisons. In assessing the merits, one is reminded that the approach is designed to approximate the spatial and/or time derivatives of the production technology using only data on prices and quantities, and thus some limitations should be expected. The limitations stem from the underlying assumptions. Constant returns to scale is a convenient although not a necessary assumption. It is not possible, however, to relax the assumptions about competitive behavior, since these are required to eliminate the first-order derivatives. Furthermore, it is not possible in the

[6] If nonquadratic approximations are used, then the replacement for (1) will involve terms which include second-order derivatives of the production function. These second-order derivatives are related to the curvature of the production function and consequently to the price elasticities of factor demand. Unless one knows the elasticities it will not be possible to use accounting methods to evaluate (1).

[7] $\rho_{ij} = \frac{1}{2}\left(\frac{\partial g}{\partial d_i}\bigg|_{i=i} + \frac{\partial g}{\partial d_i}\bigg|_{i=j}\right)(d_i - d_j).$

[8] The θ_{ij} and ρ_{ij} can also be defined for the multiple output case using the further assumption of perfect competition in the output markets (see DF 1980).

[9] The country i Malmquist productivity index can be defined as

$$(a)\ m^i(y^i, y^j, x^i, x^j) = d^i(y^i, x^j)/d^i(y^j, x^j),$$

where y^i and x^i are country i's observed output and input vectors, and d^i is country i's output distance or deflation function. Since $d^i(y^i, x^i) \equiv 1$, the right-hand side of (a) is interpreted as the maximum inflation factor for the country j output vector such that the resulting inflated output vector, m^iy^j, and x^j are on the production surface of country i. If country i has a lower productivity than country j, from the perspective of country i's production structure, then $m^i < 1$ and vice versa.

quadratic framework to find a function other than the translog that will allow elimination of the derivatives using only data on prices and quantities; while this is restrictive in theory, it is probably irrelevant in practice. The approach also relies on the sectors having production or cost functions that differ in their zero- and first-order parameters but not in their second-order parameters.

How serious are these limitations? Clearly, no index number scheme will allow production structures to be completely different. Country-specific zero- and first-order parameters allow the intercept and slope of the production technology to vary but not the rates of change of the slope. They also imply that the output-compensated factor demand elasticities will be equivalent if prices and quantities are the same, or alternatively, the slopes of the factor demand functions are equal across countries.

The assumption of competitive markets is more complicated to evaluate because the issues are both conceptual and empirical. Conceptually, government policies are distorting the productivity measures if they are resulting in inefficiencies in production. If the producers are simply operating at a different location on the production possibility surface, then there is no inefficiency in resource use, although social welfare implications are likely. If the government programs constrain producers to be inside the frontier, then inefficiencies in resource use are introduced. A frontier production model would be one way to quantify these inefficiencies and possibly explain productivity differences.

Two possible solutions to obtaining distortion-free prices include calculating implicit and explicit subsidies per commodity and adjusting observed prices accordingly, or econometrically estimating the slope of the production technology and use the estimated marginal cost functions to obtain output prices. The latter, of course, hinges on having enough data to estimate the marginal cost or marginal value product functions. The first suggestion may be more reasonable given recent research on quantifying subsidies.

Another issue involves bilateral versus multilateral comparisons. The DF methodology discussed in the previous section is directly applicable to bilateral comparisons. By computing θ_{ij} or ρ_{ij} for each pair of countries, one has information on the magnitude and rank for each region relative to the others. If one is interested in the specific magnitudes of the relative efficiency levels, then direct bilateral comparisons are needed. However, the bilateral comparisons are in theory not transitive; one cannot derive the bilateral comparison of countries i and k from information on the bilateral comparisons of these two countries with a third country j.

CCD compare productivity levels to a hypothetical country or sector, and as such their approach is base-country invariant as long as the composition and/or number of countries is fixed. The multilateral comparisons, while eliminating the intransitivities of the comparisons, obscure the meaning of the magnitude of the productivity or efficiency differential.[10] If one is interested in summarizing a large number of possible comparisons, and the actual direct comparisons are of little interest, then the CCD approach may be preferred. If the comparisons are motivated by a particular country's interests, or if the number of sectors is small, then the DF approach is in our view preferred since the benchmark is an actual country, and the efficiency differential is easy to interpret cardinally.

Both θ_{ij} and ρ_{ij} are useful as components in understanding the larger notion of competitiveness. More specifically, a gap exists, both conceptually and empirically, between a country's competitiveness at the level of delivered goods and its costs of production, or cost efficiency, at the farmgate. This gap is important in agricultural comparisons because of the presence of government programs and distortions. The importance of the productivity measures as components of competitiveness also depends upon the time perspective. In the short run, exchange rates and trade policies are also major determinants of a country's competitiveness; in the long run, productivity and cost efficiency may become more dominant factors. Holding exchange rates, trade policies, transportation costs, etc., constant, higher efficiency means a country will be more competitive. Under these conditions, θ_{ij} and ρ_{ij} are useful for assessing a country's overall efficiency level *vis-à-vis* its specific competitors.

Finally, the productivity measures and in particular, the econometric measures, may provide a preferred set of information for the competitiveness discussions, because they reflect the economic tradeoffs and the diversity in agricultural production. By contrast, costs of production measures are less reflective of real-world

[10] As DF indicate, intransitivities arise because of "cross-overs": at certain data points, country j may be more efficient than country i and the reverse at other data points. The existence of intransitivities can be of interest in and of themselves.

situations and can be misinterpreted in the sense of lending "false precision" to the cost differences among sectors.

Data Development

The USDA is currently involved in efforts to create a consistent data base for the United States, Canada, United Kingdom, France, Federal Republic of Germany, and Netherlands. The objective is to provide international data on the prices and quantities of inputs and outputs which will be useful for more than simply productivity analysis. While a detailed discussion of these efforts is beyond this paper, we briefly highlight some aspects of the ongoing efforts.

The accounting framework is modeled along the guidelines of the United Nations "System of National Accounts." This system is designed to give a systematic and comparable presentation of the activities of each agricultural sector. The agricultural accounts are based on the concept of a "national farm" that represents a single agricultural holding producing the total output of agricultural products of a country's economy. Output is defined as the quantity sold plus stock changes and own-account fixed capital formation. Stocks consist of goods in progress (e.g., immature animals) and finished products from own production.

Gross capital formation is divided into two categories: (*a*) gross fixed capital formation; and (*b*) changes in stocks. (*a*) includes nonresidential structures, other construction, vehicles and other machinery and equipment. Estimates of capital stock are constructed as weighted sums of all past investment where the weights are the asset's efficiency as of a given age. The efficiency function is approximated by a rectangular hyperbola which incorporates several types of physical depreciation (e.g., straight line, geometric, etc.) as special cases.

Because the efficiency function is applied to a broad type of assets, a distribution of service lives is assumed. This is done by constructing a "cohort" efficiency function which is a weighted average of efficiency functions calculated using various asset ages. The weights are determined by a discard density function. The capital stock estimates reflect a concave physical depreciation pattern with a truncated normal distribution of retirement ages.

Own-account capital formation is not recorded in gross capital expenditure. However, the number of animals added to the fixed capital stock can be derived. These animals are valued at their opportunity costs if prices for replacement animals are not reported. Data have been compiled on the effects of age on productivity, culling rates which allow construction of cumulative survival functions, and genetic trends in certain animal traits such as milk yield, weaning weight, fleece weight, and litter size. The genetic trend measures embodied technical change. This information allows us to construct measures of relative efficiency which are, in turn, used to aggregate past investment.

The stocks of goods held in storage exclude commodities held by intervention authorities such as marketing boards or government held stocks. Animals included as fixed capital are also excluded. The stock estimates are for the beginning of the reference period.

The stock of land is an implicit quantity index of land in farms. It is assumed that farmland within a state (region) is homogenous in quality; hence, aggregation is at the state (regional) level. The measure of labor input reflects the changing composition of the farm work force. Data on hours worked and wage rates are cross-classified by occupational and demographic characteristics. Self-employed farmers are imputed the mean wage of hired workers with the same occupational and demographic characteristics.

Conclusions

In understanding international comparisons and how they relate to a country's competitiveness, both rates of growth and differences in productivity levels are important. Econometric and index number methods are applicable for making international comparisons. The econometric approach is based on estimation of the parameters of the production technology. The economic approach to index numbers generates formulas that are easily computed using price and quantity data and, most important, the indexes mesh with economic production theory. The index number approach reviewed in this paper is based on the assumption of optimizing behavior by producers; constant returns to scale is often assumed (although this is not necessary).

This paper has focused on the economic approach to index number measures of productivity because these measures are capable of being implemented in the near future and do not require extensive time series on outputs and inputs. While the approach provides a relatively easy way of ordering countries by their produc-

tivity levels, it should not be used to replace econometric or other methods of estimation in providing a detailed understanding of relative productivity levels.

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European Community Experience in Costs of Producing Wheat

Hervé Le Stum and Denis Camaret

Wheat is a major French and European commodity. There are approximately 400,000 wheat producers in France producing 25 million metric tons of wheat on 4 million hectares. European Economic Community (EEC) wheat production is slightly higher than 70 million metric tons.

French wheat production is very intensive, as in all of the northern plains of Europe. Soft wheat is the main type of wheat produced in these plains, while Durum is cropped in the Mediterranean regions of the EEC. Yields are high in relation to North American standards. France averaged up to 6.4 metric tons per hectare in 1989, but production typically varies from 4 to 9 tons per hectare. These yields require high levels of nitrogen ranging from 150 to 200 units per hectare in three applications, similar to the U.S. corn production.

All French wheat producers belong to the Association générale des Producteurs de blé (AGPB), which is similar to the U.S. National Association of Wheat Growers.

AGPB, which is funded by wheat growers, owns two major organizations. The Institut Technique des Céréales et des Fourrages (ITCF) provides extension information to producers on how to improve production. The second organization is UNIGRAINS, which is a bank, owned and financed by the cereal growers. This bank does not loan to producers but finances the processing of cereal and animal products.

UNIGRAINS estimates the cost of production for wheat, barley, corn, rapeseed, and sunflowers. However, only wheat will be discussed in this paper, as it features the most detailed analysis.

This paper has the following objectives: (*a*) to present information regarding the costs and returns of French wheat production; (*b*) to evaluate the cost of production, study its trends, and compare costs with prices over time; (*c*) to compare the French situation with European and North American competitors (USDA cost-of-production data are available in France since 1979).

General Methodology

UNIGRAINS initiated French cost-of-production data for wheat because neither the Ministry of Agriculture nor research institutions or universities could provide information about this subject. Two methods of assessing cost of production were considered: (*a*) Starting from standards of production, in terms of labor, machinery and prices of inputs, like the USDA approach between 1974 and 1980. But this approach cannot meet the high variability in European actual farm conditions. This method proved unable to deal with the North American situation, and the USDA has modified its approach after 1980. (*b*) Consider the total farm and the total of its costs. Farm costs will likely not be equal to an optimized farm in terms of some inputs such as machinery or labor. But this method reflects the exact conditions of production in Western Europe, and in France.

UNIGRAINS selected the second method but did not have the resources to build a sample of cash grain farms. So, the selection was made using existing data. Three sources are available in France: (*a*) The European Community Network of Farm Accounts, as Réseau d'Information Comptable Agricole, RICA, in France, which is the basis of the so-called "objective method" of price establishment by the Commission, but no longer used for this purpose. But RICA provides no crop enterprise data. (*b*) The National Institute of Agricultural Research, INRA, has a good sample, but is too small (two groups of 25 farms) and located in a very narrow region of the Paris Basin. (*c*) The Institut de gestion et d'économie rurale, IGER, a federation of local accounting centers for farmers and paid by users. IGER has a data bank, which collects farm accounting records all over France, on a regional basis (French departement). This

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allows geographical approaches. The problem is that these data are not homogenous across departements. Moreover, departements where cash-crops are relatively unimportant are unable to provide data. From this data bank, UNIGRAINS collects a sample of more than 3,000 farms, located in sixteen departements (fig. 1).

In summary, IGER data do not precisely meet the study data requirements nor are they representative of the total French production because they are somewhat biased toward the northern part of France, which is the specialized area in cash-crop farming. Nevertheless, the samples represent more than half of the French wheat production.

Each farm provides to the IGER data bank its general account and direct costs per crop. The direct costs are the following: seed, fertilizer, pesticide, custom operations with corresponding labor included, and, French and European commodity specific taxes.

These taxes are included in the farmgate price and are paid by the farmers for each ton of wheat sold. French tax calculations include wheat board (ONIC) and professional organizations, general agricultural extension services, and a special added contribution to social security. This tax on the product, which is paid only on cereals and oilseeds, is added to the normal general farm taxes based on the acreage of each farm.

This level of the direct costs is named "vari-

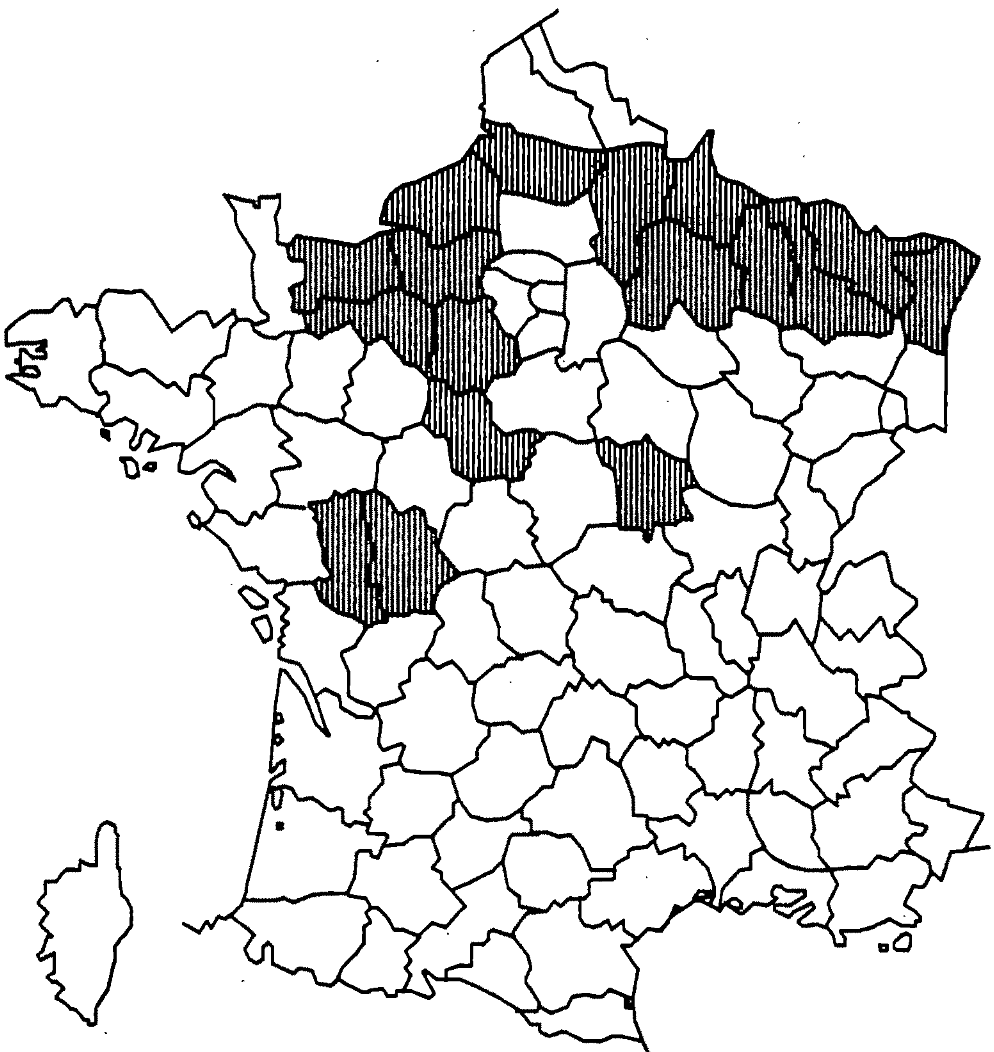

Figure 1. Areas of cost-of-production sample

able expenses." The difference between receipts and variable expenses is gross margin and provides the basis for the choice between crops in the rotation.

Indirect cash costs are repairs; fuel, lube, and electricity; hired labor; social security paid by the enterprise; insurance and general farm taxes; interests on operating loans; and general farm overhead. Allocation of indirect costs is always problematic. Different types of allocation schemes have been tested on real farms where more detailed data were available. But the key has to be a simple system that works for all farms. The results show that, for machinery, the best method is to allocate the cost in proportion of the acreage of the crop in the rotation; for other costs, the best allocation system is the proportion of the gross value of each enterprise of the total receipts of the farm. The sum of these cash costs constitutes the level 1 structural expenses. Returns over these expenses are not usually used by French farm management specialists.

Capital replacement and land costs are the level 2 structural expenses, which are a mix of cash and calculated costs. Capital replacement costs are extracted from the general farm accounts, which are based on French tax accounting rules. These costs are allocated in the same fashion as indirect costs. Machine costs are based on acreage; everything else is based on gross value. For land, no distinction is made between owned and rented land; all land is considered as rented, and in each departement the cost of owned land is calculated in the same manner as rented land.

Return over variable expenses and levels 1 and 2 structural expenses, which is defined as "agricultural income," diagnoses farm business health and is used by both banks and government institutions. Other items are seldom calculated.

Unpaid family labor is estimated from the actual presence of the family on the farm and is considered fixed. Hence, family labor is generally overestimated in comparison to technical requirements, but this reflects the situation of French and European farms, where people are full-time farmers but are not fully employed. Family labor wage rates are set at hired labor rates in the departement. Hence, considerable variability exists between regions.

The last item, the cost of nonland equity, is seldom calculated by accountants. UNIGRAINS values nonland equity at a low rate of interest (6%).

The following results of this research represent a weighted average of French production, the weighting is by the wheat production of each departement.

Main Results

The composition of the cost shows the predominance of the structural expenses (level 1 + level 2), which represents 50% of the total expenses. The variable expenses reach only a third of the cost (table 1).

While the absolute costs levels are important, it is more important to consider how costs have varied over time. UNIGRAINS files began in 1982, but data collection and processing delay the results; in the summer of 1990, only data for 1987 are available. Data for 1988 and 1989 costs are extrapolated by use of indices.

Main conclusions regarding the costs of wheat production in French francs over time are (fig. 2):

(*a*) From 1982 to 1986, the cost of production per hectare has risen 30%, then stabilized in current value.

(*b*) The variable expenses have slightly decreased after 1986, but it is difficult to stabilize structural expenses.

(*c*) The cost per metric ton displays different patterns than costs per hectare because of variations in yields: costs per ton were stable from 1982 to 1984 (1984 yields were very high), increased substantially in 1985 to 1987 (bad yields), decreased in 1988, and finally stabilized in 1989.

(*d*) Gross value of production per hectare has increased at an annual rate of 4% from 1982 to 1986. The decrease and stabilization in the following years were caused by the European Common Agricultural Policy with the scheme of Maximum Guarantee Quantities which pro-

Table 1. Cost of Wheat Production in France, by Item (Crop Year 1987)

Item	French Francs per Hectare	US$ (1987) per Hectare	Rounded %
Variable expenses	2,255	375	28
Specific taxes	515	86	6
Structural expenses (Level 1)	2,235	371	28
Structural expenses (Level 2)	1,880	312	24
Family labor	845	140	11
Cost of owned capital	265	44	3

Source: UNIGRAINS.

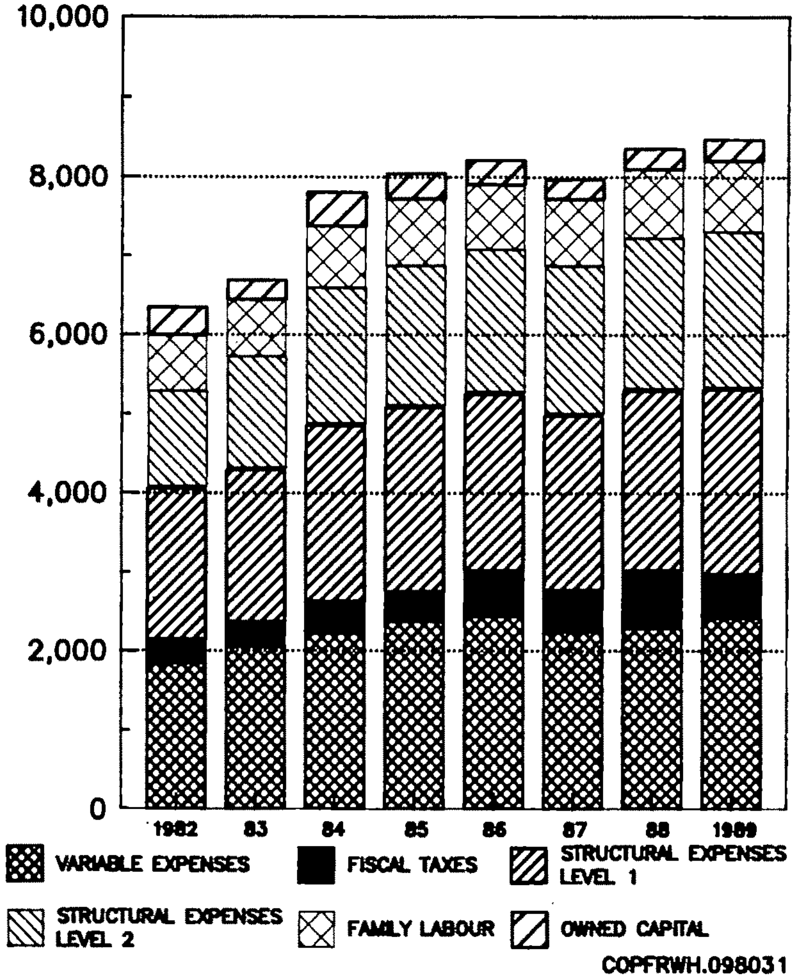

Figure 2. Cost of production of French wheat (FF/ha)

vides, as a result, a decrease in cereal prices of 3% per year.

(*e*) The net return to management and risk per hectare was positive the first years (1,000 FF/ha—143 to 124 US$/ha following year value of US$), null in 1985, very negative (−700 to −800 FF/ha = −54 to −150 US$/ha) in 1986 and 1987 and negative but near zero the last years.

Interestingly, trends in wheat production costs are considerably different when expressed in U.S. dollars (fig. 3). The value of the U.S. dollar increased by 37% between 1982 and 1985, then decreased by 33% from 1985 to 1987. The increase of the French cost per hectare in francs from 1982 to 1986 is turned into a slight decrease in U.S. dollars. The stabilization of the cost in francs after 1986 appears as an increase in dollars.

From a European point of view, wheat production has not been profitable since 1985. As a result, the cost per hectare has stabilized as farmers adapted to a changing, less profitable environment. Other indicators, as the index of income of French cash grain crops, show the same trend. In Francs, the decline reached 35% in five years in real value. Moreover, the disparity between the French farmers which are significantly larger than southern French farmers who have lower yields and incur more drought risks, is increasing over time. Unfortunately, our data cannot precisely measure the differences.

Comparisons in the EEC

UNIGRAINS has begun comparing the costs of production between different EEC countries. The costs of wheat production are compared based on 1988 data.

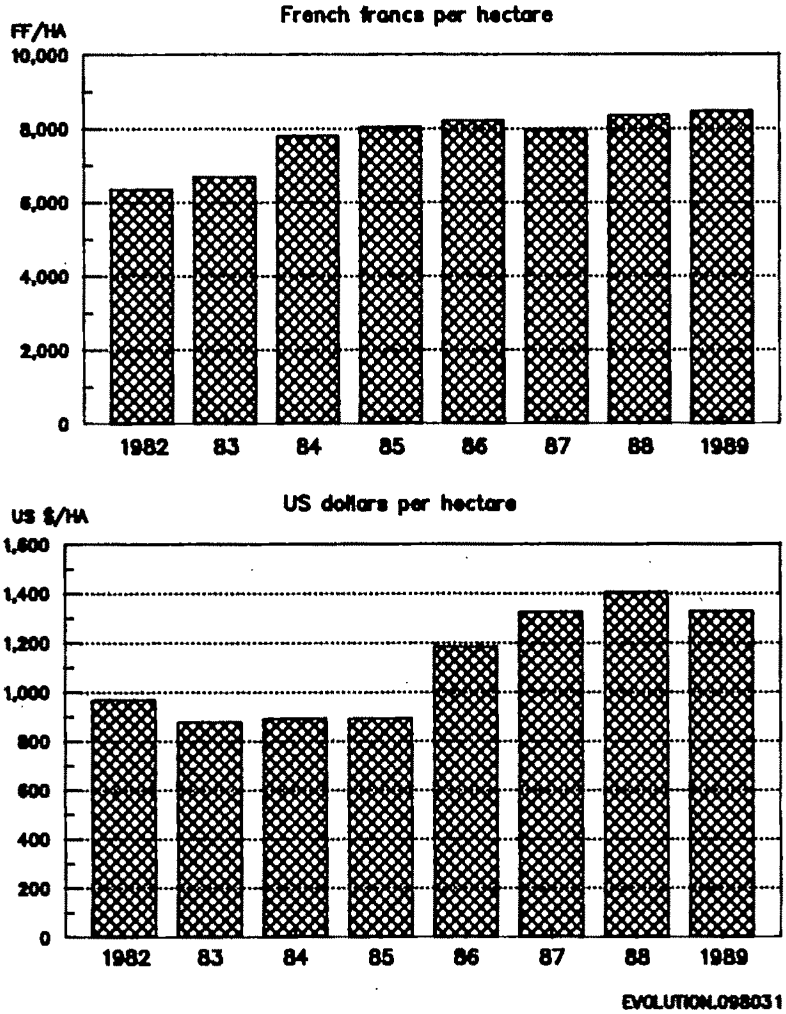

Figure 3. Evolution of the cost of production of wheat

In all countries, except the United Kingdom, it is difficult, as in France, to find good data. This task is made more difficult when the country has many small farms and is located in southern Europe. Data exist in Germany but are not easily available. In Italy and Spain, farm accounts often simply do not exist, even for large farms. Hence, research is limited to specialized grain areas with full-time farming.

Inside the EEC, problems of currencies, government programs, taxes, and price distortions exist in the same way as between EEC and USA or Australia. Hence, the comparisons are not easily made, and the analysis had to be simplified. The general scheme of analysis is the same as in the first part of this paper but COP for France in table 2, even price per ton, cannot be directly compared with those of table 1. Nevertheless, a number of rough comparisons can be made based on 1988 crop year data.

In terms of cost per hectare, the lowest COP is in Castilla-Leon in Spain. Because of the low input intensity, it generates per hectare cost of only half of the European average. Cost per hectare in East Anglia in United Kingdom and Paris Basin in France are at the same level, approximately twice as high. The Pô Valley in Italy is 10%–15% higher than France and the United Kingdom. Fionna in Denmark and Lower Saxen in Germany are 30% higher.

In terms of cost of production per metric ton, the results are not similar. The lowest costs are observed in East Anglia and Paris Basin, around 145 ECU per metric ton, 145 US$ per ton for an exchange rate of 1 for 1 (which seems to be the long-term rate), 169 US$ for 1988 exchange

Table 2. Costs of Production for Wheat in the EEC, 1988 Crop Year (commercial ECU)

	Fionna Denmark	Lower Saxen Germany	East Anglia U.K.	Paris Basin France	Pô Valley Italy	Castilla Leon Spain
Yield (t/ha)	7.2	7.2	6.9	7.3	6.7	2.7
Price per tonne	183	179	163	154	177	186
Cost per hectare	1,343	1,314	1,000	1,029	1,186 to 1,100	443
Cost per tonne	186	183	144	143	176 to 164	166
Net return per hectare after taxes	−31	+67	+83	+76	+1 to +85	+41

Source: UNIGRAINS.

rate and 178 US$ for the exchange rate of July 1990. COP per tonne in the Pô Valley and Castilla Leon are 15% higher and Fionna and Lower Saxen, 30%. So, in the European context, intensive production seems to be more competitive than extensive production.

But, in the Common Market, prices are not equalized because of monetary disparities. Prices are higher in countries where costs are high, and the differences of competitiveness are restrained a first time.

In some countries, general taxation and government policies can cancel a handicap of competitiveness and reverse profitability patterns, as in Germany (table 2).

Conclusion

The following conclusions can be made from this analysis. A large number of difficulties are encountered in both intracountry and intercountry comparisons. Intracountry results can be improved by the establishment of a series of COP. Nevertheless, the following problems must be addressed: (*a*) The sample should be extended to the southern regions of France, in order to have a more representative sample of French wheat production; this will be possible with time. (*b*) Comparisons with optimized costs should occur to allow a better appreciation of progress in production costs. (*c*) The study should include an examination of COP variability and its underlying causes. (*d*) The work with other European countries requires the building of a network of cooperation, but it will always suffer from the lack of data for some countries.

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Food Insecurity
(Mark Newman, Abt Associates, Inc., presiding)

Optimal Control of Food Insecurity: A Conceptual Framework

Truman P. Phillips and Daphne S. Taylor

During the past three decades, the focus of food security research has evolved from an examination of concepts such as nutrition, food production, and pricing policies to an examination of household and national level food security systems and mechanisms.[1] In the 1960s, research focused on expanding agricultural production and supply. In the early 1970s, the variability in food supplies led to research on buffer stocks, balance of payments stabilization, trade, and food aid policies and programs. In the 1980s, if measured by the degree to which global food supply and food stocks increased, national and international food security efforts would appear to have been successful. However, as we enter the 1990s, problems of household and individual food insecurity persist.

It is estimated that in 1989, 550 million people did not have enough to eat, and many more lacked both adequate quality and quantity of food to meet specific nutritional requirements (WFC 1990). Regionally, 60% of the undernourished live in Asia, 30% in Sub-Saharan Africa, and 10% in Latin America, with the absolute number of undernourished growing fastest in Africa. Although the vast majority of hungry people live in countries with very low average per capita incomes, food insecurity is not restricted to those countries. In the United States, it is estimated that 20 million people do not have access to sufficient food (WFC 1990).

Researchers now accept the fact that the causes of food insecurity have still not been properly addressed. In particular, it is realized that many of the earlier studies of food security failed to recognize that national food security did not imply household or individual food security, and that food security today does not imply food security tomorrow. The following quote from Simon Maxwell highlights the need for continued research at a disaggregated level while the quote from the World Food Council indicates the need to understand food insecurity as a dynamic concept.

> It ought to be axiomatic that food security planning must begin with an analysis of "who is food insecure and why": only by combining a taxonomy of food insecurity with an analysis of why it occurs can appropriate interventions be planned and their effect predicted. The identification of food insecure groups is required at different levels of aggregation: in broad socio-economic and geographical aggregates for national policy making: in more detail for the allocation of resources at regional or district level; and in enough detail to allow discrimination between individuals when it comes to implementing targeted programmes such as emergency relief or supplementary feeding. Despite the surge of interest in food security, especially in sub-Saharan Africa, these issues of description and analysis remain neglected. The gap has certainly been felt in Sudan, where the IDS review of food security issues in 1988 concluded that better understanding of food insecurity was the single greatest priority in improved food security planning. (Maxwell, p. 1)
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> Food security implies two things. First, it implies that food is available, accessible, affordable—when and where needed—in sufficient quantity and quality. Second, it implies an assurance that this state of affairs can reasonably be expected to continue; or, in other words, that it can be sustained. To put it simply, food security exists when adequate food is available to all people on a regular basis. (WFC 1988, p. 2)

In this paper a conceptual framework of food insecurity is presented which highlights both the importance of the household and the dynamic nature of food insecurity. The purpose of the paper is to describe the conceptual framework

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[1] The literature in this area is extensive. An excellent collection of research articles may be found in *Food Security: Integrating Supply, Distribution and Consumption*, by Gittinger, Leslie, and Hoisington. Other books include *Food Security for Developing Countries*, by Valdes; *World Food Security: Selected Themes and Issues*, by the FAO; *Coping with Hunger*, by Bigman; to name just a few.

and to illustrate that when expressed as an optimal control problem, it can assist in the planning and targeting of appropriate food security interventions. The next section presents the conceptual framework of food insecurity. The third section demonstrates food insecurity as a control problem for a single household and multiple households. We then provide a discussion of data implications and, finally, a summary.

A Conceptual Framework of Food Insecurity

The definition of food insecurity adopted in this paper is: A state of food insecurity exists when members of a household have an inadequate diet for part or all of the year or face the possibility of an inadequate diet in the future.

The two fundamental concepts implicit in the above definiton are that food insecurity is defined in terms of the household, and that food insecurity relates to both the current and future adequacy of the household diet.

Following from this definition, our concept of household food insecurity can be expressed mathematically as

$$FS = CS + f(R, I, HT).$$

This equation states that the determination of the future state of household food insecurity (FS) entails an assessment of the current state of household food insecurity (CS) and the likelihood of deviation from this state ($f()$). This deviation is a function of food insecurity risks (R), food insecurity insurances (I) and household types (HT). The following paragraphs define these variables.

Current State of Household Food Insecurity (CS)

This refers to the adequacy of the household's present food consumption. An assessment of the current state of household food insecurity should be based on both the quantity and quality of the household's diet and should indicate if the household is in a state of food security (all members of the household have an adequate diet throughout the year) or a state of food insecurity. States of food insecurity may be defined in terms of types of food insecurity (e.g., temporary, cyclical, chronic), levels of food insecurity (e.g., dietary intake as a percentage of an acceptable standard), or a combination of both.

Deviation from the Current State f(R, I, HT)

Deviation from the current state refers to the likelihood of deviation from the household's current state of food insecurity and is based on an assessment of food insecurity risks, insurances, and household types.

Food Insecurity Risks (R)

These refer to events which increase food insecurity, or, in other words, lessen household food consumption. Food insecurity risks can be measured both by the damage caused by these events and by the likelihood that these events will occur. Risks may emanate from natural or manmade causes and they may impact on the entire population or be restricted to selected households. Examples of risks include food shortages prior to harvest, temporary marketing problems, seasonal or unforeseen unemployment, exceptional increases in prices, civil strife, chronic poverty.

Food Insecurity Insurances (I)

These refer to actions which decrease the likelihood that risky events happen and/or their resulting damage. Food insecurity insurances may be actions taken by households, communities, or nations. Insurances may address the root causes of food insecurity or they may address the symptoms of food insecurity, namely hunger. Examples of insurances which address the root causes of food insecurity include increasing employment opportunities, land reform, and use of improved agricultural production techniques. Examples of insurances which address symptoms include local charity, supplementary feeding programs, and emergency food aid. As these examples indicate, many food insecurity insurances are provided through government policy interventions and programs.

Household Type (HT)

Household type refers to a taxonomy of household types which reflect such things as the means and methods by which households acquire food for consumption. Two broad household types are the market-food-oriented household and the nonmarket-food-oriented household. A market-food-oriented household may be defined as any

household that acquires the bulk of its food through the exchange of resources such as cash, services, or goods. A non-market-food-oriented household may be defined as any household that acquires the bulk of its food supplies through home food production. These household types may be further refined by grouping households by sources of income, by percentage of market dependence, resource base, or location such as urban or rural.

A breakdown by household type is important because food insecurity risks and insurances do not affect all households equally. For example, a risk such as a downturn in the economy or an increase in unemployment could increase the food insecurity of a market-food-oriented household but would not necessarily change the food insecurity state of a non-market-food-oriented household. Similarly, insurances which increase agricultural resources or provide new agricultural technologies could benefit the non-market-food-oriented household but would do nothing, in the short run, for an urban market-food-oriented household.

To summarize, the household in this conceptual framework is the basic building block for food insecurity analyses. By using the concepts defined in the framework to synthesize household-level data, an initial assessment may be made of the number of households (or population) that are food insecure, the severity of the insecurity, the risk factors that are contributing to food insecurity, and the insurance measures needed to combat food insecurity.[2] For policy purposes, this means that household aggregations can be used for community and national level food security planning, monitoring, and evaluation.

To further illustrate the usefulness of our conceptual framework, the following section demonstrates how our conceptual framework may be cast as an optimal control problem which may assist in the planning and targeting of appropriate food security interventions.

Food Insecurity as a Control Problem

A food security planner's ideal objective might be to provide an adequate supply of food to all people on a regular basis (WFC 1988). The challenge for the planner is to efficiently use resources (physical, monetary, or human) towards this end. In economics, this objective and challenge can be referred to as an optimal control problem: i.e., the optimal allocation of scarce resources among competing ends over an interval of time to satisfy a stated objective. An optimal control problem consists of time, an objective functional, state variables, control variables, and equations of motion (Intriligator, p. 292). Assuming that the variables of the framework can be expressed in numerical units, the following paragraphs illustrate how the components of the conceptual framework may be formalized as an optimal control problem.[3]

Time

In general, control problems require the specification of initial time and terminal time.[4] In terms of our conceptual framework, initial time, t_0, corresponds to the time when the current state of household food insecurity is evaluated. Terminal time, t_1, corresponds to the time when the future state of household food insecurity is evaluated. From a planner's point of view, the terminal time may be dictated by budgetary and political factors and is probably in the range of three to five years into the future.

States of Household Food Insecurity

Such states are represented in the control problem by state variables, $x(t)$, which characterize the system at any point in time, t. Current state (CS) is equivalent to the state of household food insecurity at the initial time, $x(t_0)$. Future state (FS) is equivalent to the state of household food insecurity at the terminal time, $x(t_1)$. For discussion purposes, it will be assumed that the state of household food insecurity ranges from 0, extreme insecurity, to 1, food security [equation (1)].

$$(1) \qquad 0 \le x(t) \le 1,$$

where $x(t)$ is a state of household food insecurity at time, t.

[2] An example of this type of analysis may be found in *Food Security: an Analysis of the SEARCA/Guelph Survey*, by Phillips and Taylor.

[3] For example, the components of the framework may be expressed in ordinal units such as months of inadequate or adequate diet or in scalar units ranging from 0 to 1.

[4] The terminal time may be undefined if transversality conditions hold; the terminal time is bounded or if it is defined by a known function (Kamien and Schwartz).

Deviations from the Current State

Deviations from the current state are represented in the control problem by equations of motion which are differential equations describing the time rate of change of state variables. Based on the conceptual framework, equations of motion describing the time rate of change in states of food insecurity may be expressed as functions of insurances,[5] risks and household types.[6]

In the discussion of the conceptual framework, it was suggested that changes in the state of household food insecurity are negatively affected by risks and positively affected by insurances.[7] It may also be assumed that the amount of food insecurity insurance required to change the state of household food insecurity is positively correlated to the severity of the insecurity. That is, to render a given change in household insecurity requires more insurance for a highly food insecure household than for a moderately food insecure household. Taking these factors into consideration, the following equation of motion is specified [equation (2)] which states that the change in a household's state of food insecurity in a given time period is equal to the amount of insurance that is provided to the household, adjusted for its state of food insecurity, minus the amount of risk faced by the household.

$$(2) \qquad \dot{x} = [\beta U(t) - \gamma(1 - x(t))] - \sigma\frac{dz}{dt},$$

where $\dot{x}$ is the time rate of change of the state of household food insecurity; β is the change in the state of household food insecurity per unit of insurance; $U(t)$, the number of units of insurance provided to the household at time t; $(1 - x(t))$, the severity of the state of food insecurity at time t; γ, the insurance penalty associated with the severity of food insecurity; $\gamma(1 - x(t))$, the additional insurance needed given the severity of the state of food insecurity at time t; $\sigma(dz/dt)$, risk, the stochastic disturbance which renders the movement of state variables undeterministic; σ, the standard deviation of the risk; and dz is the incremental of the stochastic process that obeys Brownian motion (Kamien, p. 243).

The above discussion outlines one approach to formalizing the variables of the conceptual framework into optimal control problem terminology.[8] The following sections illustrate how this specification of the conceptual model can be used as a food security planning tool for problems facing single and multiple households.

A Single-Household Problem

For the conceptual framework to be used as a food security planning tool, an objective functional must be specified. While many objective functions can be defined, for purposes of exposition, a planner's objective for a single household could be to select appropriate food insecurity insurances which result in the greatest reduction in household food insecurity within a specific time interval.[9] This objective functional is expressed as

$$(3) \qquad \text{Maximize } x(t_1) - x(t_0),$$

which states that the objective is to maximize the improvement in the household's food security within the time interval $t_1 - t_0$. Furthermore, it can be assumed that the planner is constrained by a budget which limits the amount which can be spent on food insecurity insurances and the planner requires that household food insecurity not worsen from its initial state.

Thus, the planner's optimal control problem for the single household can be expressed as

$$\text{Maximize } x(t_1) - x(t_0),$$

subject to

$$\dot{x} = [\beta U(t) - \gamma(1 - x(t))] - \sigma\frac{dz}{dt}$$

$$x(t) \geq x(t_0)$$

$$C(t)U(t) \leq B(t) \quad \text{for} \quad t = 1, 2, \ldots, t_1$$

$$0 \leq x(t) \leq 1,$$

[5] Food insecurity insurances are analogous to control variables in the control problem literature.

[6] Household types will be introduced in the section entitled "A Multiple Household Problem."

[7] Insurances may address the root causes of food insecurity or the symptoms of food insecurity. The former type of insurances contribute to a change in the state of household food insecurity, while the latter may not contribute to changes in states of household food insecurity in the long term. For this paper it will be assumed that all insurances address the root causes of food insecurity.

[8] Alternative, more realistic, and thus more complicated specifications of the model are also possible, although they are not illustrated here.

[9] Alternative objective functionals could be to minimize the time required to make a household food secure, minimize the cost of insurances required to bring about a specific change in food security, minimize the amount of insurance required to maintain current states of food security, etc.

where $C(t)$ is the cost of a unit of insurance in time t, and $B(t)$ is the total insurance budget available to the household in time t.

The maximum principle technique can be used to solve the planner's problem for the final state, $x(t_1)$, interim states, $x(t)$, as well as the timing and amount of food insecurity insurances, $U(t)$ for $t_0 < t < t_1$, given that the following variables are known: t_1; $x(t_0)$; $C(t)$; β; γ; σ; $B(t)$.

The maximum principle technique can be considered an extension of the use of Lagrange multipliers to optimal control problems and is often the most useful since in "contrast with classical calculus of variations, it can cope directly with general constraints on the control variables and, by contrast to dynamic programming, it usually suggests the nature of the solution" (Intriligator, p. 344).

For purposes of exposition, and in an attempt to highlight the substantive points of the conceptual framework rather than small complexities of the model, a more general Hamiltonian will be specified than that implied by the above statement of the single-household optimal control problem. Specifically, the constraint on the range of state variables, $0 \le x(t) \le 1$, and the constraint that the state of food insecurity can not worsen from its initial state, $x(t) \ge x(t_0)$, were not included in the Hamiltonian. In addition, the probability of a risk occurring was assumed to be 100%, reducing the risk term in the equation of motion, $\sigma(dz/dt)$, to zero. This additional assumption means that it is not necessary to utilize Itô's calculus.

Adopting the above simplifications, the generalized Hamiltonian is

$$H = x(t_1) - x(t_0) + \lambda_1(\beta U(t) - \gamma(1 - x(t))) + \lambda_2(B(t) - C(t)U(t)),$$

where λ's are costate variables.

Applying the maximum principle, assuming that $t_0 = 0$ and the insurance budget is constant through time, leads to the following solution:

$$\frac{\lambda_1}{\lambda_2} = \frac{C(t)}{\beta}$$

$$x(t) = x(t_0)e^{\gamma t} + (1 - e^{\gamma t})\left[1 - \frac{\beta}{\gamma}U(t)\right],$$

where λ_1 is the costate variable of the equation of motion, and λ_2 is the costate variable of the budget constraint.

This solution states that the change in the state of household food insecurity per unit of insurance equals the marginal cost of providing that insurance. From this general solution, it can be shown that if the state of household food insecurity is not allowed to worsen, $\dot{x} \ge 0$, then the amount of insurance offered the household is defined by the following equation:

$$U(t) \ge \frac{\gamma(1 - x(t))}{\beta}.$$

This result combined with the constraint that the state of food insecurity ranges from 0 to 1, indicates that the amount of insurance applied to the household ranges from 0 when the household is food secure, $x(t) = 1$, to γ/β when the household has extreme food insecurity. This solution is only possible if there is sufficient budget to provide the necessary insurance. That is,

$$C(t)\frac{\gamma(1 - x(t))}{\beta} \le B(t).$$

The solution to this single-household problem is as expected, namely that the marginal benefits of lessening food insecurity will equal the marginal cost of the insurance required to bring about this change. Furthermore, the reduction in food insecurity will be within budgetary constraints and will happen as quickly as possible.

A Multiple Household Problem

Expanding on the previous example, the control problem is specified again to include multiple households. While many objectives can be defined, for purposes of exposition, the objective functional for the multiple household optimal control problem will be to select appropriate food insecurity insurances over time which result in the greatest reduction in household food insecurity.

As noted in the discussion of the conceptual framework, food insecurity risks and insurances do not affect all households equally. Therefore, it is necessary to define state variables for groups of households. Such household groupings may be based on household types and states of current food insecurity. This means that the state of household food insecurity at any time t is written as $X_{hs}(t)$, where the subscripts h and s identify all possible combinations of household type and states of food insecurity at t_0. The implicit assumption is that all households of type h and current state of food insecurity s are considered homogenous, facing the same risks and responding equally to the same insurances. The

planner's objective is to determine the optimal allocation and scheduling of targeted insurances to these *hs* household groupings. State variables are still restricted to values between 0 and 1.

Thus the planner's optimal control problem for multiple households can be expressed as:

$$\text{Maximize} \sum_{h=1}^{N} \sum_{s=0}^{1} n_{hs} X_{hs}(t_1) - \sum_{h=1}^{N} \sum_{s=0}^{1} n_{hs} X_{hs}(t_0),$$

subject to

$$\dot{X}_{hs} = [\beta_{hs} U_{hs}(t) - \gamma_{hs}(1 - X_{hs}(t))] - \sigma_{hs} \frac{dz}{dt}$$

$$X_{hs}(t) \geq X_{hs}(t_0)$$

$$C(t) \sum_{h=1}^{N} \sum_{s=0}^{1} U_{hs}(t) n_{hs} \leq B(t)$$

$$0 \leq X_{hs}(t) \leq 1.$$

The subscripts are defined as follows: h is the household type, ranging from 1 to N, at t_0; s is the state of household food insecurity, ranging from 0 to 1, at t_0. The variables are defined as follows:

$X_{hs}(t)$ is the state of food insecurity for each household in the *hs*th group at time t;

$X_{hs}(t_0)$, the state of food insecurity for each household in the *hs*th group at time t_0;

$X_{hs}(t_1)$, the terminal state of food insecurity for each household in the *hs*th group at time t_1;

n_{hs}, the number of households in the *hs*th group;

$\dot{X}_{hs}$, the time rate of change of the state of food insecurity for each household in the *hs*th group;

$U_{hs}(t)$, the number of units of insurance provided to each household in the *hs*th group at time t;

$\sigma_{hs}(dz/dt)$, the amount of risk facing each household in the *hs*th group;

σ_{hs}, the standard deviation of the risk facing each household in the *hs*th group;

dz, the incremental of the stochastic process that obeys Brownian motion (Kamien, p. 243);

$C(t)$, the cost of a unit of insurance at time t;

$B(t)$, the total insurance budget available in time t;

N, the number of defined household types.

The definitions of the parameters are: β_{hs} is the change in the state of food insecurity per unit of insurance for the *hs*th household group, and γ_{hs} is the insurance penalty associated with the severity of food insecurity for the *hs*th household group.

The problem is solved for the states of food insecurity for each *hs* household group at terminal time, $X_{hs}(t_1)$, and interim time, $X_{hs}(t)$, and the amount and timing of food insecurity insurance available to each household in each *hs* group, $U_{hs}(t)$ for $t_0 < t < t_1$, given that the following variables are known: t_1; $X_{hs}(t_0)$; N; n_{hs}; β_{hs}; γ_{hs}; σ_{hs}; $C(t)$; $B(t)$.

Utilizing the same simplifications as were used to solve the single-household problem, the generalized Hamiltonian for the multiple household problem is specified as

$$H = \sum_{h=1}^{N} \sum_{s=0}^{1} n_{hs} X_{hs}(t_1) - \sum_{h=1}^{N} \sum_{s=0}^{1} n_{hs} X_{hs}(t_0) + \lambda_1(\beta_{hs} U_{hs}(t) - \gamma_{hs}(1 - X_{hs}(t))) + \lambda_2\left(B(t) - C(t) \sum_{h=1}^{N} \sum_{s=0}^{1} U(t)_{hs} n_{hs}\right).$$

And this leads to the following solution:

$$\frac{\lambda_1}{\lambda_2} = \frac{C(t) n_{hs}}{\beta_{hs}}$$

$$X_{hs}(t) = X_{hs}(t_0) e^{\gamma_{hs} t} + (1 - e^{\gamma_{hs} t})\left[1 - \frac{\beta_{hs}}{\gamma_{hs}} U_{hs}(t)\right],$$

where λ_1 is the costate variable of the equation of motion, and λ_2 is the costate variable of the budget constraint.

Again, from this general solution, it can be shown that if the state of household food insecurity is not allowed to worsen, $\dot{X}_{hs} \geq 0$, then the amount of insurance offered the *hs*th household is defined by the following equation:

$$U_{hs}(t) \geq \frac{\gamma_{hs}(1 - X_{hs}(t))}{\beta_{hs}}.$$

This result combined with the constraint that the state of food insecurity ranges from 0 to 1 indicates that the amount of insurance applied to a household ranges from 0 when the household is food secure, $X_{hs}(t) = 1$, to γ_{hs}/β_{hs} when the household has extreme food insecurity and is only possible if there is sufficient budget to provide the necessary insurances. That is,

$$C(t) \sum_{h=1}^{N} \sum_{s=0}^{1} n_{hs} \frac{\gamma_{hs}(1 - X_{hs}(t))}{\beta_{hs}} \leq B(t).$$

The solution to the multiple household problem thus suggests how different groups of households should be targeted for food insecur-

ity insurances so as to bring about the greatest reduction of food insecurity.

Data Implications

The data requirements to undertake the above analysis include household-level data for the identification of household types, the assessment of current states of household food insecurity, and the identification of risks and insurances. Community and national level data are required for the identification of risks and insurances which do not originate at the household level. Current research and surveys in food security are now providing this type of data (Phillips and Taylor).

The area of greatest data paucity is that required to develop the equations of motion, specifically the estimates of β and γ. While estimates of β and γ are limited, it is possible to use expert opinion to find reasonable proxies of the changes that can be expected in household food insecurity per unit of risks and insurances. Previous studies related to nutrition, production, price analysis, etc., can be used to provide additional estimates of these parameters.

Summary

Briefly, our conceptual framework embraces the following components: states of food insecurity (both current and future), risks, insurances, and household types. It contributes to the understanding of food insecurity in a number of ways. It focuses on the household where the problem of food insecurity exists. It recognizes that there are different types and levels of food insecurity and can accommodate alternative definitions. It identifies causes of and possible solutions to food insecurity by examining the impact of risks and insurances on households. It recognizes that these causes and solutions vary for different household types, and it captures the dynamic nature of food insecurity by examining both the current and future adequacy of household diets.

Furthermore, the paper illustrates that the conceptual framework may be quantified when expressed as an optimal control problem. The optimal control problem allows for dynamic optimization which can assist with the planning and targeting of food insecurity interventions. While the optimal control problem specification of our conceptual model was simplistic, it is hoped that the reader can appreciate how the concept can be used to address the problem of food insecurity in a holistic manner, and that the model can be refined to reflect more complicated situations.

To fully realize this potential, there is need for further research. There is need for analysis which quantifies the linkages between risks, insurances, and states of food insecurity. There is also need to develop a taxonomy of household types which captures the behavioral attitudes of households and governments toward food insecurity and its alleviation. Further research, of course, is contingent on the collection of household-level data, relating to the concepts defined in our conceptual framework of food insecurity.

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Measuring Food Security in Africa: Conceptual, Empirical, and Policy Issues

John M. Staatz, Victoire C. D'Agostino, and Shelly Sundberg

"Food security is access by all people at all times to enough food for an active and healthy life."—World Bank

The definition of food security has broadened since the term first came to prominence at the 1975 World Food Conference. Discussions of food security in the mid- and late 1970s were strongly influenced by the shortfall in world food production and run-up in prices early in that decade. Initially, food security meant avoiding transitory shortfalls in the aggregate supply of food. By the early 1980s, however, the world food supply situation had evolved markedly. The famines striking Africa took place in a world awash in grain. Clearly, inadequate levels of global food supply were not the cause of hunger. Sen's work focused attention on the lack of access by households and individuals to food because of low incomes (entitlements) as a cause of food insecurity, and other research has shown that for most of the hungry in the world, this lack of access is chronic, not transitory. Thus, the conceptual understanding of food insecurity has gradually evolved over the past fifteen years to include not only transitory problems of inadequate supply at the national level but also chronic problems of inadequate access and unequal distribution at the household level.

Despite a broader understanding of the complexity of food insecurity, policy makers must still look for easily measured indicators to design programs to reach the food insecure. Often, these indicators are measures of regional or national food supply or its correlates (such as rainfall), as current information on household or individual entitlements to food is usually lacking. Some policy makers may think of supply shortfalls or the lack of domestic food self-sufficiency as the "true" food insecurity problem.[1] More commonly, they may simply believe that the supply indicators they use are highly correlated with the true but unmeasured indicators of household or individual access to food.

A critical question then becomes to what degree are commonly used indicators of food security, as measured at one level of aggregation such as the nation or region, correlated with indicators of access to food at other levels, such as the household or the individual?[2] This paper addresses these issues, drawing on preliminary findings from research carried out in the OHV zone of southern Mali. The sample included approximately ninety rural households in eight villages, for which coarse grain (millet, sorghum, and maize) production and transactions data were collected over the period 1985–88 and food

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[1] Shortfalls in domestic supplies of grain, resulting in massive commercial or food aid imports, may represent real food insecurity to those decision makers concerned about the overall foreign exchange position of the importing country or its ability to retain its sovereignty in the face of pressure from its food suppliers (Staatz and Wohl). Because of space limitations, this type of insecurity is not addressed here, but it is important to bear in mind when considering why some policy makers give such emphasis to domestic food self-sufficiency even though it is well known that such self-sufficiency is no guarantee against hunger among the population.

[2] The term region, as used in this paper, refers to a subnational area, such as a province, not a regional grouping of countries, such as the Sahel.

consumption, expenditure, and anthropometric data were collected in 1988 and 1989.[3]

National versus Regional Food Security

Following the trauma of the great Sahelian drought of the early 1970s, most Sahelian states, including Mali, made attaining food self-sufficiency a central pillar of their food strategies (Staatz and Wohl). Hence, the degree to which domestic consumption of basic staples was covered by national production became a key measure of food security for national policy makers. Yet, attainment of national food self-sufficiency does not guarantee adequate access to food in each region of the country. Indeed, the restrictions on private marketing of grain that most Sahelian countries imposed until the 1980s (especially the interdiction of inter-regional grain trade) helped assure that national self-sufficiency did not translate into adequate regional food supplies. However, even with the removal of restrictions on the private trade, inadequate transportation infrastructure and weak effective demand may result in gluts in one region not being translated into adequate access to food in another.

In addition, policies designed to alleviate national problems of food surpluses or shortages can exacerbate regional entitlement disparities, particularly when markets are poorly integrated and regional income inequalities are great. For example, as a result of a record coarse grain harvest in Mali in 1989, the government emphasized export promotion to boost farm-level prices and hence the incomes of those farm households (mainly in the CMDT zone of southeastern Mali) that are net sellers of grain. Some local officials in the grain-deficit zones of the West through which the exports pass, however, have attempted to block them to prevent higher prices in this very poor region. This highlights the food-price dilemma inherent in food policy, that is, the difficulty of reconciling the conflicting interests of net buyers and sellers of food (both as individuals and as regions). This dilemma is severe in many African countries, even though most of the population is rural, because many small farmers are net purchasers of basic staples (Weber et al.).

Regional versus Household Food Security

In Mali, as in many other Sahelian states, policy makers rely heavily on regional indicators of food production and prices to target food aid and general development assistance. For example, all the districts (*arrondissements*) monitored for potential food shortages in Mali (the "at risk" zones) are located north of the fourteenth parallel, in the lower rainfall areas of the country (Staatz et al.). Yet, many households in the "surplus zones" south of the 14th parallel lack adequate access to food. Even in the southern CMDT zone, the most productive agricultural region of the country, where per capita coarse grain production in 1987 averaged 311 kilograms (kg) (compared with an estimated consumption requirement of 188 kg), only 43% of households that cultivated manually (27% of total households) had production above the consumption requirement. In contrast, 89% of households having at least some animal traction equipment met that norm.

Northern areas of Mali are generally perceived as being more prone to food insecurity than southern areas because of their lower and more erratic rainfall levels. Over the 1970–85 period, the annual rainfall in northern OHV ranged between 550 and 760 millimeters, compared to a 850–1,000 millimeter range in southern OHV (D'Agostino, p. 48). According to CESA-MSU survey results, average per capita grain production during the 1985–87 period was 16% to 65% higher in southern OHV than in the north (D'Agostino, Dioné, and Staatz). Yet, when sample households were ranked in terms of their food consumption security in 1988, there was no significant difference between north and south (table 1).[4]

The main reason that differences in regional agricultural production potential were not correlated with differences in consumption security is that households in the northern, more arid area, have more diverse income sources and rely more on the market for their food supply than their southern counterparts. In 1987–88, sample

[3] OHV stands for *Opération Haute Vallée*, or Upper Niger River Valley Development Authority. The OHV households were part of a larger survey of farm households in southern Mali, which also included the CMDT zone (*Compagnie Malienne du Développement des Textiles*). The CMDT zone is the main cotton-producing area of the country and also the area that produces the bulk of Mali's marketed surplus of coarse grains. For details, see Dioné.

[4] The consumption ranking was based on a scale that took account of the following indicators for each household: number of meals eaten per day, number of meals which included meat or fish, number of ingredients in the sauce served with the main staple (a measure of dietary diversity), and number of times per day a nutrient-poor gruel was prepared as the main meal.

Table 1. Household Consumption Security Rankings, Northern and Southern OHV Zone, Southern Mali, 1988 (percentage of households by category)

Consumption Security Ranking	South	North	Total
High	8.9	7.8	16.7
Average	25.6	26.7	52.2
Low	17.8	13.3	31.1
Total	52.2	47.8	100.0
Chi-squared (df = 2) = .79			

Source: D'Agostino and Sundberg, forthcoming.
Note: The consumption ranking was based on evaluation of the following indicators for each household: number of meals eaten per day, number of meals which included meat or fish, number of ingredients in the sauce served with the main staple (a measure of dietary diversity) and number of times per day a nutrient-poor gruel was prepared as the main meal.

households in northern OHV obtained 39% of their household grain supplies from the market, compared to only 8% in the south. The market becomes particularly important late in the crop year. In the period just before harvest in 1988, grain from the market served as the base for 67% of the meals in northern OHV, compared with 28% in the south.

The importance of reliance on the market in the north is reflected in how market purchases influenced household consumption security, as measured in table 1. Whereas the level of market purchases is negatively correlated with a household's consumption security in the south, it is positively correlated with it in the north (table 2). In other words, southern households attempt to assure household food security through own production and tend to purchase grain only when this strategy fails. Northern households, in contrast, develop more diverse income sources that are less directly dependent on rainfall levels (table 3) and use revenues from those activities to purchase food. The northern households, living in a more risky environment, have evolved strategies that allow them to mitigate the effects on consumption security of fluctuations in household crop production to a greater extent than their southern counterparts, who have developed strategies to exploit the (normally) higher agricultural production potential of their area. These findings are similar to those observed in northern and southern areas of neighboring Burkina Faso (Reardon, Matlon, and Delgado).

Table 3. Distribution of Major Income Sources in the OHV by Subregion (% of men and women's responses, aggregated over three seasons), 1988–89

Income Sources	OHV-South (N = 706)	OHV-North (N = 363)
Agriculture and wild products	55.1	29.4
Commerce	15.0	10.4
Artisans' activities	7.9	20.1
Livestock	6.1	16.5
Prepared foods	4.1	16.8
Labor and migration remittances	6.0	4.1
Gifts	4.8	1.1
Other	1.0	1.6

Source: Sundberg, 1989a.

Table 2. Correlates of Household Food Security in the OHV by Subregion, 1987–88

	OHV-South		OHV-North	
Indicator	t-ratio	signif.	t-ratio	signif.
Coarse grain production per household	2.32	.03	2.62	.02
Coarse grain production per capita	.23	.82	2.49	.02
Coarse grain availability per household	1.96	.06	2.57	.02
Coarse grain availability per capita	−.31	.76	2.03	.06
Coarse grain purchases per household	−2.24	.04	2.17	.05
Coarse grain sales per household	1.49	.15	−1.30	.21
Number of farm household workers	2.21	.04	1.48	.16
Number of revenue sources per household	2.31	.03	0.36	.72
Household size	1.66	.11	1.45	.17
Ownership of animal traction equipment	chi square = 9.23	.06	chi square = 7.00	.14

Source: D'Agostino and Sundberg, forthcoming.
Note: Unless otherwise stated, the statistics presented in this table are t-values from tests of the equivalence of the population means for consumption-secure and consumption-insecure households. A significant positive t-ratio indicates that consumption-secure households measured significantly higher on this variable than consumption-insecure households. For animal traction equipment ownership, three levels of ownership were measured (nonequipped, semi-equipped, and fully equipped). The chi-square test measures whether the distribution of ownership was different between consumption-secure and consumption-insecure households.

The findings suggest that the functioning of rural product and factor markets in grain deficit zones plays an extremely important role in determining household food security. In particular, the ability of rural distribution markets to deliver grain reliably to grain-deficit rural households at low cost is central to the ability of these households to assure adequate levels of consumption. Yet, many of these rural distribution markets are thin, and prices are consequently volatile.[5] Price volatility hits hardest those poor households that sell grain early in the season to meet pressing cash needs (especially tax payments) and repurchase grain late in the season to meet consumption needs (D'Agostino and Staatz).

The ability of rural households to obtain income to purchase the grain depends critically on the functioning of the markets for the goods and services these households sell (table 3). In addition, the capacity of these households to weather short-term fluctuations of real income depends on the functioning of rural capital markets. In the long run, the goal of policy should be to decouple a household's food consumption status from short-term fluctuations in agricultural production by improving both rural capital markets and the markets for the goods and services the households sell (von Braun).

If differences in per capita grain production levels across geographic zones are not good predictors of household food consumption security, what are? Table 2 summarizes the factors that were significantly different between consumption-secure and consumption-insecure households within northern and southern OHV. A few indicators, such as coarse grain production and availability per household, are positively correlated with consumption security within both subzones, indicating that even though the northern households are more market oriented, own production continues to play an important role in their food strategies. In both subzones, larger households (which have more diverse income sources) tend to be more consumption secure than small households. But what is striking in table 2 is that many indicators are valid for one subregion but not the other. For example, size of the farm labor force and ownership of animal traction equipment are more significantly correlated with household consumption security in the south than in the north because in the south agriculture contributes more to family income. Most striking, the level of grain purchases is negatively correlated with household consumption security in the south but positively correlated with it in the north, for reasons explained above.

This diversity in the subregional correlates of household food security suggests that any attempt to develop indicators to monitor household consumption security needs to be area specific. Few easy-to-monitor indicators are robust across all subzones. One possible method to obtain indicators is to use local village informants. The two enumerators employed by the consumption survey (women with 9th grade educations) were asked to give their subjective rankings of the household consumption security of all the sample households. The correlation between these rankings and those based on the scale described in footnote 4 was .87, suggesting that local informants may be a cost-effective way of monitoring household food security. A major challenge, however, would be to assure the objectivity of their rankings if such rankings served as the basis for the distribution of benefits, such as food aid, to food-insecure households.

Regional versus Individual Food Security

If aggregate measures of regional food production are not good indicators of household food security, it is even less likely they will be reliable guides to individual nutritional status as measured, for example, by anthropometrics. In order to evaluate children's nutritional status, children aged 0–7 years from the sample households were weighed and measured in three different seasons to evaluate their degree of protein-energy malnutrition (PEM): early November 1988 (just before the main grain harvest), early February 1989 (immediate post-harvest period), and late August 1989 (peak of the hungry season).[6] Aggregating across the three rounds, the overall rate of short-term PEM, or wasting, as measured by weight-for-height, was 4.2%. The prevalence of chronic PEM, or stunting, as measured by height-for-age, was 37.0%.

The fact that northern households were at least

[5] Between October 1987 and August 1988, the prices paid by sample households in northern OHV for millet and sorghum more than quadrupled, from under 29 CFA.F/kg to slightly over 130 CFA.F/kg. (D'Agostino and Staatz).

[6] Sample sizes for the 3 rounds were 268, 277, and 256, respectively. A child was considered wasted if her weight-for-height fell at least two standard deviations below the median NCHS/WHO growth reference curves. Similarly, a child was considered stunted if her height-for-age fell at least two standard deviations below the NCHS/WHO median curves. For details, see Sundberg 1989b.

as consumption-secure as their southern counterparts is borne out in the anthropometric measures. Children in the northern areas had significantly lower levels of chronic PEM than children in the south, 23% versus 43% ($t = 4.73$, $p < .01$). There was no significant difference in the prevalence of wasting between north and south, although mean weight-for-height is significantly lower in the south ($t = 2.96$, $p = .003$). One possible explanation for the substantially lower incidence of growth stunting in the north is that health and sanitation problems (particularly the incidence of malaria) are likely to be greater in the more humid south. Given the strong synergies between disease and malnutrition, the disease problems may have been manifested in more growth stunting in the south.[7] Cultural differences between the two subzones, such as child feeding practices, may also have been a factor, although the vast majority of the sample in both areas were of the same ethnic group. (The issue of child-feeding practices will be explored in future analysis).

Household versus Individual Food Security

Poor health and sanitation and inappropriate child feeding practices may prevent adequate levels of household consumption security from translating into satisfactory nutritional status for the most nutritionally vulnerable members of the households, such as preschool children or pregnant and lactating women. Indeed, for the OHV zone as a whole as well as for each subzone, the data indicate no correlation between the household consumption security ranking reported in table 1 and either of the anthropometric measures (the prevalence of wasting and stunting within the household). This is a striking finding: it implies that even if one could accurately assess household food security as measured by the frequency of meals and indicators of dietary diversity used in the consumption-security scale, this alone would not be a reliable guide to the nutritional status of the children in the household. The household consumption ranking derived by the enumerator, however, was positively correlated with long-term nutritional status ($r = .43$, $p < .01$) in northern OHV, thus suggesting that the use of local informants may be an effective tool for monitoring both household food security and individual nutritional status.

For both the northern and southern subzones, there are very few significant correlations between the anthropometric measures and the household-level economic and demographic indicators shown in table 2. In the south, there are no significant correlations between long-term nutritional status and household-level indicators. Short-term status, however, is negatively correlated with two variables: coarse grain purchases per household ($r = -.40$, $p < .01$) and the degree to which the products from women's individual fields were sold ($r = .49$, $p < .001$). On average, the more grain purchases a household made, the worse off its children were nutritionally. This finding parallels the negative correlation between purchases and household food security in the south (see table 2). This underscores the conclusion that, in the south, higher purchases reflect a failure of the agricultural production strategy, which renders the household more vulnerable to consumption and nutritional deficiencies. Second, in households where women sold a greater part of the products from their individual fields, children were more likly to be wasted. A possible explanation is that women who retained their own production for home consumption increased the diversity of their children's diet, thus contributing to a better nutritional outcome. This hypothesis will be explored in further analysis of the food consumption data.[8]

In the north, short-term nutritional status is negatively correlated with household size ($r = -.48$, $p < .01$), number of farm workers ($r = -.43$, $p < .01$), household grain sales ($r = -.53$, $p < .001$), and gifts of grain received by the household ($r = -.39$, $p < .01$). The direction of correlation between household size and farm workers, on the one hand, and nutritional status, on the other, is the opposite of that between these same demographic variables and household food security (although the latter correlates are not statistically significant—see table 2). Nutritional status may decline as household size increases because, although staple grain quantities may increase commensurately with the number of consumers, typically sauce ingredients are not

[7] The village with by far the worst anthropometric rankings was the only village in the sample surrounded by low-lying wet areas, suggesting that the incidence of mosquito-borne diseases may have been higher there. This village was also one of the most isolated of the sample villages from surrounding markets, thereby hindering the ability of households to diversify their incomes.

[8] Sales from women's individual fields are not correlated with the overall level of grain sales of a household or with the number of nonagricultural enterprises. Thus, it does not appear that women who sold a high proportion of the output from their fields did so because their households had fewer alternative income-earning opportunities than their neighbors.

augmented by a similar ratio and are therefore stretched thinner in larger families, thus lowering the per capita intake of protein, vitamins, and minerals. Households in the north with higher total grain sales are likely to have more wasted children, perhaps because these transactions represent distress sales of grain, which is not truly surplus but is sold only to meet pressing cash needs. Finally, it is intuitive that households with more malnourished children received a larger quantity of gifts of grain.

Long-term nutritional status in the north is positively correlated with only a single variable, grain production per capita ($r = .44$, $p < .01$). Thus, in spite of the importance of nonfarm activities in the northern households' income strategy, agricultural production remains vital to both the overall food security of the household (table 2) and the nutritional status of its vulnerable members.

These findings suggest that a number of factors intervene in the OHV to prevent adequate levels of household food availability from translating into satisfactory child nutritional status. Poor health and lack of adequate nutrition education are likely to be among the most important of these variables. Policy therefore needs to focus on developing mechanisms to address these variables. Work in Guatemala has highlighted the importance of community-level health and nutrition investments in improving the link between higher rural incomes and the nutritional status of children (Von Braun, Hotchkiss, and Immink). In the OHV, short-term and long-term malnutrition rates varied widely by village. While by far the highest rates were found in one of the most isolated villages with poor health facilities (see footnote 6), among the other seven villages, the incidence of malnutrition did not seem to vary systematically with the level of village infrastructure, as measured by the presence of dispensaries, maternal health clinics, and schools. Just because a village had such infrastructure, however, does not mean it was effective, as lack of supplies and poorly trained and poorly motivated staff often impede the facilities' effectiveness. Such facilities probably also need to focus their activities more closely on nutritional issues to have a strong impact.

One should be cautious in interpreting and generalizing from these preliminary results. The OHV zone has poorly developed markets, a low degree of cash-cropping, and weak village infrastructure. One important area for further research is to replicate this type of study in areas such as the cotton-producing CMDT zone, where cash-cropping, off-farm income earning opportunities, and the degree of village-level health infrastructure are higher to see if the lack of correlation between indicators of household food security and child nutritional status holds up.

Conclusions

The analysis has shown that for Mali, commonly used indicators of food security at the regional and national level are often poor predictors of household and especially individual food security. Hence, they may be poor guides to interventions to help the hungry. This poses three challenges for policy makers. One is to develop more accurate, area-specific indicators and cost-effective means to monitor individual and household food security.

The second is to decouple household and individual food security from the vagaries of local agricultural production. Reforms and infrastructure improvements aimed at improving the ability of private traders to move food at low cost among regions and improving the functioning of product, service, and factor markets to allow the food insecure to earn reliable income streams are crucial. Such improvements must be tied to improvements in productivity in cereals cultivation in order to help drive down the real cost of food to rural consumers. Over the long run, strengthening rural capital markets to allow households to bridge temporary shortfalls in income also is important. In designing reforms, it is important to have information on the degree, timing, and conditions of participation of the food insecure in these various markets in order to maximize the impacts of such reforms on the hungry (for examples, see Staatz). The third challenge for both researchers and policy makers is to develop a better understanding of how disease, intrahousehold food distribution, and nutrition education mediate the relationship between household food availability and individual food security. The goal should be to develop mechanisms to strengthen the currently weak relationship in Mali between higher rural incomes and improved nutrition of vulnerable groups.

Finally, it is important not to misinterpret these findings. Although rural households in northern OHV rely heavily on the cereals market and on nonagricultural enterprises to assure their food security, one should not conclude that increasing agricultural productivity is unimportant to them. Even within the north, household consumption security and long-term child nutri-

tional status are correlated with labor productivity in grain production, demonstrating that own production continues to play an important role in these households' food strategies. Even more important, the success of a strategy of relying on the market depends critically on the ability of the food system to produce and deliver grain to these rural households at low price. Given Mali's landlocked position, a large part of this grain will continue to be produced domestically, at least in the medium term. Thus, improvements in productivity in cereal farming as well as marketing are needed.

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Poverty, Food Intake, and Malnutrition: Implications for Food Security in Developing Countries

Maurice Schiff and Alberto Valdés

The focus of this paper is on the relation between household income, food intake, and nutritional status in less developed countries (LDCs). This article presents a framework which relates explicitly household behavior patterns with the public policy options designed to improve the nutritional status of the poor in rural and urban households.

Nutrition and Income: The Statistical Evidence

Recent literature on the interaction between nutritional status, nutrient intake, and household income has made recommendations on how to improve nutrition based on parameters from empirical studies of food expenditure systems (Behrman and Deolalikar 1988, Alderman, Schiff and Valdés 1990a). However, the policy recommendations derived from the analysis depend critically on the definition of nutrition and, more broadly, on the conceptual framework used. In particular, critical elements of the pathway from changes in income to its effect on nutritional status are still questioned.

It is useful to highlight some fundamental findings on which there is a fair degree of agreement. Estimates from food expenditure systems yield income elasticities of nutrients (ϵ_{ny}) somewhat smaller than, but not significantly different from, 1.0. These are derived indirectly by estimating the income elasticities of food expenditures (also close to 1.0) and by assuming constant nutrient-to-food conversion factors.

More recently, for rural South India, Behrman and Deolalikar (1988) find that the expenditure income elasticity of food for the (6) food aggregates is close to one. However, for the major nine nutrients, the income elasticities (ϵ_{ny}) are not significantly different from zero. As income increases, a larger proportion of food expenditures is spent on non-nutrient food attributes such as diversity of products consumed, freshness, taste, convenience foods which save time in their preparation, and others. Similar results are found for low-income households in Pakistan by McCarthy and in several other studies. Based on this evidence Behrman and Deolakikar (1987) conclude that nutrition is unlikely to improve with income. However, if it can be shown that nutrition is not identified exclusively with nutrient intake, then the policy implications might be strikingly different. This is a major objective of this paper.

The Framework

The starting point is that the nutrition level or status (N) of a household depends only in part on its nutrient intake (n). It also depends on other privately and publicly provided goods and services.[1]

At the household level, we can think of a process of "producing" nutrition (a nutrition production function), where N is a function of the current as well as lagged values of (a) the nutrient intake (calories, protein, vitamins, etc.) which we call n, (b) the input of non-nutrient food attributes which affect N, such as freshness of the foods purchased, their cleanliness, and their storability, which we call q, (c) the privately provided inputs which may affect N, such as the time and care to prepare food including cleaning, cooking, boiling water, and other inputs (refrigeration) that ensure that the food does

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The views expressed in this paper are the sole responsibility of the authors and should not be attributed to the World Bank or to IFPRI.

[1] A formal development of this framework is found in Schiff and Valdés (1990a).

not become contaminated or spoiled, which we call p, (d) the publicly provided inputs which would include potable water, sewerage, electricity, nutritional information, etc., which we call k. The production of N is also partly determined by the individuals' health status, age, sex, and location (rural or urban). A fall in health resulting from causes other than a fall in n, q, p, or k above—say, because of a reduction in medical services—will result in a fall in N.

Only in the extreme case of famine (i.e., as nutrient intake approaches zero), would all food expenditures be allocated to nutrients n, the impact on N of the other variables, particularly q, would tend to zero and only an increase in nutrients would have a significant impact on N. In that case, ϵ_{ny} would be close to one. However, the vast majority of the population in developing countries does not fall under this extreme case of famine.

In a broader sense, the variable of concern is household's welfare, an important component of which is the health status (H) of its members, which depends in part on their nutritional status. As with nutrition, at the household level we can think of a health production function, H, which is a function of (a) nutritional status referred to above, (b) privately provided inputs (p), (c) publicly provided inputs (k), and (d) a variable (m) of current and lagged values of additional inputs affecting health. In fact, the variable m consists of both privately provided inputs (amount and quality of child care, hygiene, etc.), and of publicly provided inputs (medical services, information on hygiene and child care, and other). Finally, the production of health is also a function of age, sex, and location (rural or urban) of the individual. Thus, health depends on privately and publicly provided inputs directly, as well as indirectly through their effect on nutrition.

Because the functions N and H may vary according to sex, age, location, and other individual characteristics, the impact on N and H of changes in each determinant n, q, p, k, and m also may vary according to those characteristics.

This framework allows us to further elucidate the question of whether income gains in low-income communities could reduce malnutrition (raise N), even when they have only a very marginal effect on nutrient intake at the household level. How these two variables, N and H, respond when income gains occur among low-income households is then the central concern in this paper.

From the production function of nutrition (N) defined above, we can derive the income elasticity of nutrition (See appendix for details.):

$$\epsilon_{Ny} \equiv A + \epsilon_{NH}\epsilon_{Hy},$$

where N is level of nutrition, H is level of health, y is the household's income, ϵ is the income elasticity, and A is the partial elasticity of N with respect to income (for a given health status) and includes the impact of income on n, k, q, and p.

Similarly with health status, given the production function of health described above, we derive the income elasticities, namely

$$\epsilon_{Hy} \equiv \epsilon_{HN}\epsilon_{Ny} + B,$$

where B is the partial income elasticity of H (for a given N). Variable B includes the income elasticities of privately provided inputs ϵ_{py} of publicly provided inputs ϵ_{ky} and of the other variable ϵ_{my} affecting health (such as medical services, information on hygiene and child care, and others). Solving for ϵ_{Ny} and ϵ_{Hy}, we obtain

$$\epsilon_{Ny} = \frac{A + B\epsilon_{NH}}{1 - \epsilon_{NH}\epsilon_{HN}}, \text{ and}$$

$$\epsilon_{Hy} = \frac{B + \epsilon_{HN}A}{1 - \epsilon_{NH}\epsilon_{HN}}.$$

We postulate that $\epsilon_{qy}, \epsilon_{py}, \epsilon_{ky}, \epsilon_{my} > 0$; that is, increases in household's income will be accompanied by an increase in the demand for food "quality"—e.g., freshness, cleanliness, level of processing, and taste of purchased foods (q)—in the care in preparing food, and in the use of household appliances such as refrigerators (p), and in more income spent on potable water, electricity, and sewerage systems (k). Also, richer households will use more medical and other health-related services, and may provide health-related child care (m). The positive income elasticities for q, p, k, and m imply that $A > 0$ and $B > 0$, which in turn implies that $\epsilon_{Ny} > 0$ and $\epsilon_{Hy} > 0$. Consequently, the impact of income on N may be significant, even though nutrient intake remains unchanged or increases only slightly with income.

What we are trying to emphasize here is that to assess the impact of income on nutrition, one should not simply examine the impact on the input n but should look at the entire production function N. Furthermore, if the ultimate concern is with improving the health status H (N being one input in the production of H), then again the impact of income on health status H may be quite important. The fact that the nutrient in-

come elasticity is close to zero ($\epsilon_{ny} = 0$) and the food expenditure elasticities are close to 1.0 ($\epsilon_{Fy} = 1$) implies that the demand for non-nutrient food attributes (variety, storability, cleanliness) is high at those low income levels ($\epsilon_{qy} > 1$).

This framework is consistent with the finding, for example by Shah in rural India, and more recently Behrman and Deolalikar (1987), that even at such a low level of family income, as income increases, household's demand a wider variety of food products with a larger quantity of non-nutritive attributes (freshness, taste, processing, etc.). At the same time, however, the actual increase in nutrient intake associated with increases in the household's income is not significantly different from zero. Thus, families have a choice of spending increments in food expenditures on nutrients n but choose to spend their additional income on non-nutrient food attributes (q). And this choice, depending on which element of q is selected (say, freshness rather than taste), might even lead to an increase in nutrition or health.

Thus, the common practice of estimating the number of hungry and undernourished by comparing calorie and other nutrient intake with requirement standards implies that, in addition to ignoring the impact of intputs of non-nutrient attributes (q) and privately provided inputs (p) on nutrition, no weight is given to household preference. No matter how closely related, food adequacy (measured by nutrient intake) and nutrition level are not the same thing. The problem of food adequacy may or may not reveal itself as a nutrition problem; and a nutrition problem may or may not be the result of an inadequate supply of food.[2]

Policy Implications

Considering that the policy objective is to raise the level of nutrition or health, the approach developed above suggests that, except in the case of famines, a variety of alternative policy instruments is available and their relative merits may change according to location (rural or urban), initial conditions of infrastructure, etc. It also suggests that income will affect nutrition (and health) through its impact on q, p, and H (and m), even if it has little or no impact on nutrient intake n.[3]

Education undoubtedly plays an important role; one might expect the nutrition and health-related child care to improve with the level of the mother's education. In his study for India, Padmanabha finds that infant mortality falls both in rural and urban areas as the literacy and formal educational level of the mother increases. The evidence may not be entirely conclusive, as income may be positively correlated with the mother's education and was not controlled. García and Pinstrup-Andersen, in their study on the Philippines, find that the mother's education strongly affects the food consumption and nutritional status of preschoolers.

If the concern is with the production of health, and taking infant mortality as one indicator of health, Padmanabha argues that in rural areas in India, the main causes of death are tetanus, pneumonia, dysentery, and typhoid. These diseases are mainly conditioned by the absence or availability of basic facilities such as reliable water supply, sanitation (k), and basic child care services (m), so that nutrient intake does not seem to be the major factor. This confirms the results obtained by Castañeda for Chile, where the most important variable explaining the remarkable reduction of infant mortality in Chile from 107 per 1,000 in 1965 to 19.4 per 1,000 in 1986 was the increase in urban coverage of potable water and sewerage. Differences in such coverage were statistically more important than the positive impact of the available nutritional programs addressed to mothers. Thus, governments may have to increase the level and quality of publicly provided inputs (k and m above) in order to have a lasting impact on nutrition and health.

Providing information and education on hygiene and child care may also be effective ways of raising nutrition and health. Direct demonstration in the rural areas like in the Iringa Integrated Nutrition Program in Tanzania, or provision of information via television, which has been very successful in raising privately pro-

[2] Of course, in the extreme case of famine, malnutrition is the result of inadequate food supply.

[3] If, alternatively, nutritional status is measured as (n), then N is not responsive to y, given that nutrient consumption has been found to be rather unresponsive to changes in income. Thus, transfer programs will be ineffective means to improve nutrition. Similarly, as argued by Alderman, a weak link between income and nutrition implies that nutrition is to some degree buffered from the downswings in the local economy. Under such scenario, and given that definition of N, for income to have an impact on nutrition, policies must be designed to raise the income elasticity of nutrient intake (ϵ_{ny}); some analysts have argued that raising the mother's education could be another way to do it.

vided inputs (p) and (m) in Chile, are logical approaches to exploit the complementarities in the production of health and nutrition. Here, we refer to the private component of m, but, as mentioned earlier, there is also a public component of m. Also, policies designed to raise the nutrient content of some food ingredients, such as food fortification programs, lead to an increase in the level of nutrition by raising n.

Conceptually, the framework presented above can help in the evaluation of public investment programs to raise health and nutrition for the poorer households. However, in order to devise effective policies to raise H and N, research efforts should be directed at the empirical estimation of (a) the technological production functions of N and H, to know the impact of p, q, k, and m on N and H; and (b) the behavioral relationships to estimate ϵ_{py}, ϵ_{qy}, ϵ_{ky}, and ϵ_{my}, so as to compare the effectiveness of raising N and H through y, and through k and m (public components)—or a combination of both; and (c) the costs of providing the services, so as to identify and select cheaper and more efficient programs designed to raise the nutritional and health status of the poorer households.

One would expect that the parameters of these functions N and H differ according to age, sex, income class, and rural and urban characteristics. The estimation of these parameters should be part of the research agenda.

The Distinction between Urban and Rural Populations

The distinction between urban and rural households could raise a particularly complex issue. For governments to provide medical services and drinking water and sewers in urban areas is probably considerably less expensive than to provide it for rural areas. Given the lower population density in the latter, the cost per household scattered over large areas would be considerably higher. On the benefits side, they are probably lower in rural areas, considering that the lower population densities in rural areas would reduce the need for publicly provided sewers, drinking water and other such service.

Thus, if the low levels of N and H are the social concern, raising those levels in urban areas by increasing expenditures on k and on public components of m may be an efficient public policy. However, this may very well not be the case for rural areas because of higher costs and lower benefits of providing k and the public components of m.

What then is the prescription for rural areas? One important implication is that nutritional and health status in rural areas will then largely depend on the levels of inputs (p, q, and the private components of m), which are provided by the households. These levels depend on income, so that raising rural household's income can raise their nutritional and health status. For example, it may be easier to make a significant impact on incomes in a rural community through a variety of agricultural programs and policies than it is to appreciably increase the provision of sewerage or of health care delivery.

We are back then to the long-debated question on how to best raise farm income. One way would be to reduce the taxation of agricultural production caused by sector-specific and economy-wide policies in LDCs.[4] Another would be to increase public expenditure in those factors which raise land and labor productivity. In principle both are necessary and the right balance between them is an empirical question to be addressed on a country-by-country basis.

Concluding Comments

While food is continuously referred to in this paper, little is said about agriculture. There is, however, a strong link with agriculture because, as the analysis suggests, in rural areas the nutritional and health status will largely depend on the levels of private inputs (p, q, and the private components of m), which are provided by the households. These levels depend on income, so that raising rural income can raise their nutritional and health status.

The evidence suggests that the development strategies since World War II in most developing countries grossly undervalued the potential contribution of agriculture to economic development. Preliminary estimates for eighteen LDCs show that in most of these eighteen countries, the agricultural sector lost approximately one-fourth of agricultural GDP during 1960–84, as a result of the sectoral and economy-wide price interventions (Schiff and Valdés 1990b). The cumulative effect over time of such a transfer of income out of agriculture must have had a significant repercussion in aggravating poverty in

[4] An analysis of the impact of those policies for 18 developing countries during 1960–84 is provided in Krueger, Schiff, and Valdés.

rural areas. According to the conceptual link between income, nutrition, and health developed earlier, this evidence on income transfers suggests that these domestic economic policies probably had very detrimental effects on nutrition and health status of the poorest segments of the population. Policy reform in the developing countries should make an important contribution in alleviating rural poverty in developing countries.

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Appendix

Derivations

We propose the following alternative definition for the nutrition production function:

$$(1)\quad N = N(n, q, p, k, H; S, E, L), \qquad \epsilon_{Nn}, \epsilon_{Nq}, \epsilon_{Np}, \epsilon_{Nk}, \epsilon_{NH} > 0,$$

where n is a vector of inputs of nutrients, q is a vector of inputs of non-nutrient food attributes, p is a vector of other privately provided inputs, k is a vector of publicly provided inputs, H is health status, S is sex, E is age, L is urban or rural location, and where n, q, p, and k are lag polynomials in those variables, reflecting the effect of current as well as lagged values of those variables.

A health production function can be defined as

$$(2)\quad H = H(N, p, k, m; S, E, L), \quad \epsilon_{HN}, \epsilon_{Hp}, \epsilon_{Hk}, \epsilon_{Hm} > 0,$$

where m is the vector of current and lagged values of additional inputs affecting health, such as medical services, information on hygiene and child care, and other. Health depends on p and k directly, as well as indirectly through their effect on N.

Because N and H depend positively on current as well as lagged values of their arguments, the long-run elasticities will tend to be larger than the short-run elasticities. Also, the functions N and H may vary according to sex, age, location, and other individual characteristics, so that the elasticities of N and H with respect to their arguments may also vary according to those characteristics.

Finally, in terms of income elasticities:

$$(3)\quad \epsilon_{Ny} = \epsilon'_{Nn}\epsilon_{ny} + \epsilon'_{Nq}\epsilon_{qy} + \epsilon'_{Np}\epsilon_{py} + \epsilon'_{Nk}\epsilon_{ky} + \epsilon_{NH}\epsilon_{Hy} \equiv A + \epsilon_{NH}\epsilon_{Hy},$$

and from equation (2) the income elasticity of health status is

$$(4)\quad \epsilon_{Hy} = \epsilon_{HN}\epsilon_{Ny} + \epsilon'_{Hp}\epsilon_{py} + \epsilon'_{Hk}\epsilon_{ky} + \epsilon'_{Hm}\epsilon_{my} \equiv \epsilon_{HN}\epsilon_{Ny} + B,$$

where ϵ' is a row vector. Solving for ϵ_{NY} and ϵ_{HY} from equations (3) and (4), we obtain

$$(5)\quad \epsilon_{Ny} = \frac{A + \epsilon_{NH}B}{1 - \epsilon_{NH}\epsilon_{HN}}, \text{ and}$$

$$\epsilon_{Hy} = \frac{B + \epsilon_{HN}A}{1 - \epsilon_{NH}\epsilon_{HN}}.$$

We postulate that $\epsilon_{qy}, \epsilon_{py}, \epsilon_{ky}, \epsilon_{my} > 0$; that is, an increase in household's income will tend to be accompanied by an increase in the demand for food "quality," e.g., freshness, cleanliness, and taste of purchased foods (q), in the care in preparing food, and in the use of household appliances such as refrigerators (p), and in more income spent on potable water, electricity, sewerage systems, etc., (k). Also richer households will use more medical and other health-related services and may provide health-related child care (m). Thus, $A > 0$ and $B > 0$. Since, for stability, $1 - \epsilon_{NH}\epsilon_{HN} > 0$, this implies that,

$$\epsilon_{Ny} > 0 \text{ and } \epsilon_{Hy} > 0.$$

Food Insecurity: Discussion

Joachim von Braun

The notion of food security and the research on it has come a long way since the 1973 world food crisis. The three papers reflect the shift from a production orientation to a consumption and health focus and from country-level to household-level analyses. They emphasize disaggregated approaches for the research agenda by proposing disaggregation among and within households, among regions, and over time. The papers do not address, however, the critical issue of seasonality of food security.

Three broad, new issues are emerging from persistent problems which must be kept in perspective: (*a*) the risk of temporary global food shortages, (*b*) the fast disappearance of the easy option of expansion of cropped area to achieve food supply expansion, and (*c*) the increasing emergence of the food security problem as a problem of the urban poor in low income countries.

Household-level analyses risk ignoring these broad challenges to food security and heading toward targeted programs to mitigate food insecurity, even where policies to overcome growth and employment constraints and market failures may be the feasible first-best solutions.

The important point made by the theoretical paper of Schiff and Valdéz is that complex factors, other than income-nutr*ient* relationships, are important for the income-nutr*ition* relationship. Schiff and Valdéz appropriately critique income-pessimism regarding the nutritional improvement effects of income growth as derived from partial analyses which leave out health and other interactions with income. Evidence from household survey analysis has accumulated in support of their point. Also, cross-sectional country-level data for rural malnutrition show a strong relationship to income at low income levels: Between $300 and $600, the income elasticity of nutritional improvement is about 0.4 (fig. 1). Lack of public action for health and sanitation seems to be an important reason undercutting the nutritional benefits of income growth.

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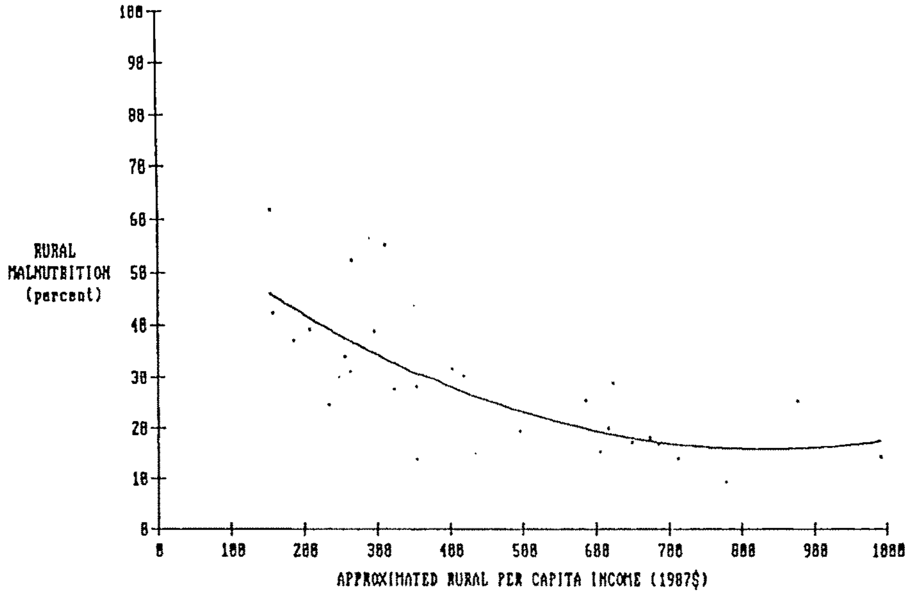
This paper stimulates thoughts on two broader issues: the type of growth for food security, and the role of public interventions for nutritional improvement.

The Phillips and Taylor paper suggests an innovative approach by casting the food security planning problem in the optimal control framework and emphasizes the dynamic risk problem of food security. While data and empirical problems loom large if the concept were applied, the concept as such may help to sharpen the debate on food security, which frequently suffers from imprecise goals-instruments separations. A basic question, however, arises from the proposed control instruments, "insurances" against food insecurity: Should these "insurances," conceptualized as programs by Phillips and Taylor, not be better dealt with as elements of insurance markets so as to give focus to overcoming failure in these markets?

The paper by Staatz, d'Agostino, and Sundberg is based on a rich primary data set and carries the point that even simple empirical analysis of real-world household food security gives interesting insights which need to enter the feedback to proper conceptualization of the food security program in specific areas. The paper utilizes an ordinal food security index, which is not convincing as food insecurity is defined as a cardinal problem: the probability of falling below some absolute consumption or nutrition cut-off point. The statistical testing of the relationship is partial and cross-sectional, not multivariate and dynamic, as would be desired.

The policy research agenda on food security comprises a growth and policy-instruments perspective. To the extent that employment-expanding growth reduces absolute poverty, food security and nutrition are enhanced. However, even steady growth in well-functioning market environments does not take care of the household food security risk in LDCs in an acceptable time. For rapid reduction of absolute poverty, the set of policy instruments comprised of self-targeting public works, price stabilization, a fresh look at efficient feeding schemes, health and sanitation promotion—tailored to specific country circumstances—needs to be deployed rap-



Source: von Braun and Pandya-Lorch.
Note: Percent below −2 standard deviations (Z-scores) of weight for age of preschoolers. Each point in the figure represents a country.

Figure 1. Rural income and rural malnutrition in developing countries with GNP per capita of less than US$1,200

idly. Institutional capacity to assess and respond to food insecurity (including decentralized institutions to monitor, design, and supervise implementation of food security policy modules) should grow as a consequence of collaborative research.

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Abstracts

Symposia

End-User Computing for Agricultural Economics Research: The Promise and the Challenge. James Horsfield (ERS USDA) and Dean T. Chen (Texas A&M University), organizers; Dean Chen, moderator; Bruce McCarl and James McGrann (Texas A&M University), John Okay (Office of Information Resources Management, USDA), Bruce Scheer and Gerald Leeper (Sparks Commodities)
Emerging technologies for end-user computing (EUC) hold the promise of another revolution by expanding the role of computing in ways that may transform both the research process and the nature of research itself. This symposium addressed four major issues regarding the EUC development for agricultural economic research: "Where are we now in the transition to EUC?" "Where do we want to go in the next 3–5 years?" "Managing the Transformation" and "Next Steps." Three presenters explored these questions from the university, government, and business perspectives. McGrann described the evolutionary process, responses and implications as well as the future role of agricultural economists in universities. Okay outlined the strategic plan for USDA and discussed the ways of managing the future environment. Leeper provided a business view on emerging data needs and future directions for decision-support tools. Chen summarized emphasizing user/user interfaces for EUC development.

Sharecropping: Is It a Remnant from a Peasant Economy or a Modern Way to Deal with Information and Risk? Hyunok Lee, moderator (ERS USDA); Avishay Braverman (World Bank), Keijoro Otsuka (Tokyo Metropolitan University), Jeffrey Reidinger (Michigan State University), Robert Chambers (University of Maryland), D. Gale Johnson (University of Chicago)
Despite the long history of share tenancy, there is little consensus in the literature concerning the causes and effects of share tenancy. The symposium reexamined share tenancy from the perspective of recent advances in information economics. Braverman provided an overview on share tenancy issues ranging from the traditional inefficiency argument to various explanations on the existence of share tenancy. Otsuka suggested a framework to integrate the Cheungian notion with imperfect monitoring. Reidinger discussed share tenancy from the social economic viewpoint arising between two social classes, landlord and sharecropper. Chambers discussed share tenancy in U.S. agriculture and emphasized that U.S. share tenancy must be examined as a contract emerging from merging two firms, the landlord and the tenant. Johnson concluded that the share contract may not result in efficiency loss and he stressed the usefulness of short-term share contracts as a way to enforce the contract by the landlord.

Global Grain Distribution Systems: Impediments to Increased Exports Leo C. Polopolus (University of Florida) and Roland R. Robinson (CSRS USDA), moderators; Rodman Kober (Continental Grain) and C. Phillip Baumel (Iowa State University), Robert Hauser (University of Illinois) and Barry Parker (E. D. and F. Man International Futures), Myron R. Laserson (Central Trading System), Steven Fuller (Texas A&M University), Won W. Koo (North Dakota State University), and Lowell D. Hill (University of Illinois)
The primary purpose of this symposium was to identify the transportation and infrastructure barriers in domestic, transoceanic, and foreign distribution sytems that impede the efficient movement and effective marketing of U.S.-produced agricultural commodities. Kober and Baumel argued that a truly national economy cannot operate efficiently without an integrated nationwide transportation system. This could include federal government ownership of rail rights-of-way, which are now privately owned. As impediments to increased exports, Hauser and Parker contended that import-port development is the most important research issue. Laserson and Baumel provided a critique of the Soviet Union's grain distribution system. The Soviet Union has major transportation and distribution problems between production fields and consumer locations, as well as between import ports and points of consumption. Fuller provided a comprehensive outline of grain transportation research needs which included the following areas: rural roads and bridges, ocean freight markets, truck/rail/barge markets, rail/barge capacity, rate determination, and interdependence of modes in grain distribution systems. Koo argued that the United States has a comparative advantage in exporting agricultural products because of not only advanced production technology and farming practices but also because of an excellent transportation system. Hill summarized the discussion by identifying the following impediments to grain transportation and distribution: physical impediments, logistical impediments, and policy impediments and barriers.

Millionaire Farmers and the Equity of Payments. Bernard Stanton (Cornell University), Robert Dubman (ERS USDA), Gregory Hanson (Pennsylvania State University), Terry Hickenbotham (ASCS USDA), Dan Sumner (Deputy Assistant Secretary for Economics, USDA), Gerald Whittaker, moderator (ERS USDA)
The equity of government payments to wealthy farmers became a large issue during the 1990 farm bill debate. The popular press contained contradictory statements about how many farmers were millionaires, the level of payments received, etc. Stanton

discussed several statistical issues including published (but likely reconcilable) differences in USDA reported statistics on payments. He also presented distributional information showing payments highly skewed to the highest decibel of producer recipients. Dubman and Hanson made the key points that only 10% of commercial farmers are millionaires from an equity standpoint, and that only about 1% of the millionaire farmers are financially vulnerable. Millionaire farmers could better withstand tighter payment caps than other commercial farmers. Hickenbotham provided an alternative perspective by pointing out that farm programs may function better in terms of supply control by not limiting payments to the larger, wealthier producers. He also made the point that the development of ASCS data to assist policy makers in evaluating payments levels and their impact would require massive commitments of USDA programming resources that are not readily available. Sumner focused on the political process which included the relatively new element of some environmentalist organizations not opposing payments to the largest, wealthier producers in order to preserve USDA clout on conservation controls. There were several recurring themes: the importance of reliable data with regard to payments distribution, the singular subsidy nature of the peanut and sugar programs, and the persuasive power of special interest groups by commodity and region.

The Sustainable Development of Tropical Rainforests: Economic, Resource, and Environmental Issues. Kenneth Baum (USDA ERS) and Vince Cusumano (ST USAID), organizers; Thurman Grove (Cornell, ST USAID), moderator; Alfredo Sfeir-Younis (World Bank), Michael Nelson (Economic Committee for Latin America), and Douglas Southgate (Ohio State University)

The sustainable development of tropical forests and other complex natural resource systems can be addressed using economic theory and analysis relating complex interactions among ecological, technological, socioeconomic, institutional, and policy objectives. The development of a more comprehensive and coördinated research program within agricultural economics relating to the sustainable development of tropical forest ecosystems needs to be more fully addressed. Agricultural economics can play an important information generating role in several areas: (*a*) formulating alternative policies and programs relating to incentives for sustainable development and management of tropical rainforests; (*b*) evaluating the linkages among economic, ecological, and environmental benefits and costs of tropical forest resource development activities; and (*c*) developing more comprehensive evaluation criteria and analytical methodologies providing policy tradeoff information to supplement rate of return and cost-benefit measures now used by many governments and multilateral institutions. Economic knowledge is an essential element for developing alternative policies and strategies affecting public and private sector investment and development decisions, and introducing and implementing economically efficient and ecologically sound incentives to preserve and manage tropical rainforest ecosystems.

Results from the Social Science Agricultural Agenda Project (SSAAP). Glenn L. Johnson (Michigan State University), organizer and moderator; James Bonnen (Michigan State University), Fred Buttel (Cornell University), William Brown (Central Michigan University), R. James Hildreth (Farm Foundation)

The session opened with a discussion of the background and organization of the Social Science Agricultural Agenda Project (SSAAP) of three years duration. SSAAP originated from dissatisfaction with the funding and administration of the rural social and basic social sciences in the agricultural establishment (AE). SSAAP seeks improved work (research, extension, teaching, advising, consulting, administering, and entrepreneurial) agendas, administration, and funding to increase rural social science (RSS) contributions to the solution of societal problems. Improved partnerships are sought with the technical agricultural sciences and the basic social, physical, and biological sciences including the ancillaries—philosophy, mathematics, and statistics. SSAAP has developed and presents balanced agendas for (*a*) disciplinary as well as multidisciplinary problem solving and subject-matter work; (*b*) the four driving forces for rural improvement—technical advance, human capital formation, institutional and policy improvements, and enhancement of natural and manmade resources; and (*d*) cross-cutting improvements in the supporting basic social sciences, in databases, and in the handling of ethical issues. SSAAP has also developed and presented more traditional agendas to assist farmers, agribusinesses, and consumers both domestically and abroad.

A lively one-hour discussion centered on increasing incentives for doing multidisciplinary problem solving and subject-matter work, administrative problems, funding possibilities, work on problems of disadvantaged rural farm and non-farm groups, and the rural social sciences' need for a standing organization such as SSAAP. Interventions, questions, and comments were from a wide variety of administrators, researchers, teachers, and extension personnel in a standing-room-only crowd of participants.

International Trade and Economic Development. Larry D. Sanders and Mike Woods (Oklahoma State University), organizers; David Henneberry (Oklahoma State University), Fred Ruppel and Michael Mazzocco (Texas A&M University), Parr Rosson (Texas A&M University) and Hal Harris (Clemson University), Warren Trock (Colorado State University)

Existence of a global economy continues to increase in significance. Rural communities tied to export-based farm production are especially insensitive to international forces. Frustration among educators, analysts, and public officials has often led to poorly coordinated educational efforts. This panel provided extension and research program ideas for community leaders, business managers, and public decision makers. Texas survey results showed that small business exports can be enhanced with targeted programs and research. Ways to establish export resource networks for business and public decision makers were discussed. Results of a survey of community leaders were examined to offer program and research opportunities and internationalize community economic development efforts.

1990 Farm Bill—A Discussion of Content and Impacts. Ron Plain (University of Missouri), organizer; Craig Infanger (University of Kentucky), moderator; Harry Baumes (ERS), Robert Young (Senate Agriculture Committee), Abner Womack (University of Missouri), and Ron Knutson (Texas A&M University)

The emerging 1990 farm bill was discussed in this symposia session by four presenters with intimate knowledge and experience with the political and economic forces which are shaping the new legislation. Baumes discussed the highlights of the different commodity programs in the House and Senate versions of the 1990 farm bill. Young explained the political environment in the U.S. Congress and how that has shaped the legislation in the last few months. Womack reviewed the current economic situation and outlook and discussed the impact on the emergence of 1990 farm legislation which reflects the new economic stability in agriculture. Knutson presented several challenges for the research agenda and researchers regarding existing and emerging legislation. Infanger moderated a lively question/answer period which focused primarily on the political options and outcomes including questions and comments from two former USDA assistant secretaries and participants from the U.S., Canada, and other countries.

Economic Policy Liberalization in Latin America: Implications for Agricultural Development. Philip F. Warnken (University of Missouri), organizer; James T. Reorden (MUCIA), moderator; David Franklin (Sigma 1 Corporation), Dale Colyer

Latin American nations are liberalizing trade policies and correcting macroeconomic imbalances. While the pace of policy reform varies from country to country, from the region as a whole, there is a definite movement away from policies that have been counterproductive to economic growth and development, especially for the region's agriculture. In the 1970s, many Latin America nations reduced or eliminated agricultural export taxes and the most negative industrial import substitution policies. But with global recession and inflation, mounting debt loads and balance of payments crises of the 1980s, there was a retrogression. Governments controlled exchange rates, and used import quotas and licenses to offset balance-of-payments difficulties. To contain domestic inflation, price ceilings were often set on basic goods, especially foodstuffs, and food imports were directly or indirectly subsidized. In many nations, export taxes were raised or reimposed and agricultural input subsidies curtailed to reduce fiscal deficits. In the 1980s, pressure from international financial and donor entities compelled policy reform. Recent and current trade and macroeconomic policy liberalizations in the region are significant and pervasive. Nations are lifting foreign exchange and interest rate controls, cutting export taxes, reducing or eliminating trade quotas, licenses and duties, and reducing or eliminating price and marketing margin controls, consumer subsidy programs, and parastatal market interventions.

China, Eastern Europe, and the USSR: Alternative Approaches to Political and Economic Reforms and the Implications for Agriculture. Shwu-Eng Webb and Nancy Cochrane, (USDA ERS) organizers; J. B. Penn (Sparks Commodities), moderator; D. Gale Johnson (University of Chicago), Frederick Crook, Nancy Cochrane (ERS USDA), Karen Brooks (University of Minnesota) and Karl Skold (Quaker Oats)

Johnson contrasted conditions in China, the USSR, and Eastern Europe across three topic areas: changes in ideology relative to private property, the effects of centralization on economic efficiency, and differences in technology levels. His general observations were corroborated by the three subsequent papers. Webb and Crook argued that China must implement genuine marketing reforms to sustain economic growth generated by reforms in rural production systems. The rapid increase in urban subsidy expenditures that has exacerbated inflation and growing concerns with falling grain production has caused China to recentralize its agricultural production. Cochrane noted that the transition to market economies in Eastern Europe will be difficult because of institutional rigidities inherited from the Communists. However, most of the new governments seem firmly committed to making full marketing reforms. Eventually the contradictions arising from only partial marketization should disappear. Brooks observed that Soviet land tenure reforms were ineffective because there has been no reform of price and input policies which favor inefficient firms. Marketing reforms and improvement in transportation systems are imperative for the success of Soviet economic reforms. Skold used Stavropol's experience to illustrate needs for improving technological efficiency and economic information. Penn summarized findings from these four papers and audience discussions.

Agricultural Livestock Outlook Programs: Effective Marketing Tools or Just an Academic Exercise? Mark R. Weimar, organizer; Terry L. Crawford, moderator; Ken E. Nelson (USDA ERS), Scott Irwin (Ohio State University), and Carl W. O'Connor (Oregon State University)
The efficacy of U.S. Department of Agriculture (USDA) and University Extension Outlook Programs were discussed. USDA livestock programs were evaluated graphically and statistically using Theil relative change statistics Ul, Um, Uc, Us, mean percent error, and mean absolute percent error. No attempt was made to characterize whether forecasts were good or bad, but beef and cattle production and price forecasts were obviously biased and reasons for the bias were discussed during the session. The methodology of USDA forecast development was also discussed including the diversity of agencies within the USDA that are on the Interagency Commodity Estimates Committees. One discussant noted the group dynamics involved in determining the official USDA forecast. Another discussant pointed out that by benchmarking USDA 7-market barrow and gilt prices and Omaha Fed Steer prices by the corresponding live animal futures price forecasts, traders could not use the USDA forecasts to make money. He also noted that USDA hog price forecasts were significantly different in bias and variance from the live hogs futures prices; but USDA live cattle price forecasts were biased while futures were not, and the variance of the two series were significantly different. The other discussant noted that even though the forecasts appeared inaccurate that most of his requests for information were for outlook-type information. He also pointed out that he relied on USDA outlook information extensively and adjusted it for his regional seasonality.

The Agricultural Trade Negotiations: What Is Achievable? George E. Rossmiller (NCFAP RFF), moderator; M. Ann Tutwiler (NCAP RFF), Craig Thorn (FAS USDA), Timothy Josling (Stanford University), T. K. Warley (University of Guelph), Fred Sanderson (NCAP RFF), John Schnittker, and Douglas Kelley (Agriculture Canada)
Tutwiler reported that the comprehensive proposals of late 1989 still reflected a wide gap between the U.S. and Cairns Group objective of fundamental policy reform and the more limited Western European and Japanese objectives of restraining the trade-distorting effects of existing policies. Thorn pointed to the June 1990 report of the chairman of the agricultural Negotiating Group as an indication of the EC's isolation in the face of a broad consensus on a rules-based multipronged solution involving cuts in internal support, market-access, and export subsidies. Josling concluded that a broad aggregate measure of support (AMS) would not be acceptable as the only policy commitment, but some version of it would probably be retained to scale down internal supports. Warley saw agreement in principle on a traffic-light approach to internal subsidies, but much work remains to be done on classifying specific policies into three categories: green (non-trade distorting and therefore noncountervailable), amber (subject to surveillance and AMS reduction) and red (to be phased out). Sanderson suggested that waning prospects for adequate cuts in the AMS and for measurable commitments on policy reinstrumentation had led the exporting countries to revert to the traditional focus on border measures. Agreement on partial tariffication was unlikely so long as the EC insisted on simultaneous rebalancing of tariffs and the retention of variable levies and subsidies. Improved market access might be achieved via tariff quotas, and an agreement to limit and reduce export subsidies also seemed possible. Schnittker felt that the U.S. would be able to adjust its policies to comply with the likely results of the negotiations. Grain support levels will be cut in any case because of budget pressures. Sugar, peanut, and milk producers will resist but will not be able to block a successful conclusion of the Uruguay Round. Hedley (Agriculture Canada) said that a fundamental policy review was underway in Canada, focusing on transportation subsidies, decoupled income stabilization accounts, and greater flexibility in the dairy and poultry sectors. He foresaw no major difficulties in adjusting to the likely outcome of the negotiations.

Grades, Standards, Safety, and Quality: Incompatible Bedfellows. Henry Bahn (ES USDA) and Bruce Bainbridge (Colorado State University), moderators; Tom Schotzko (Washington State University), Lowell Hill (University of Illinois), Roberta Cook (University of California, Davis), and Barry Goodwin (Kansas State University)
Coordinated grades and standards with end use properties and food safety are needed. Government standards are used to provide standards for communication but do not necessarily change as rapidly as the market place requires. Schotzko emphasized the ability of high-grades in the Red Delicious apples, which emphasize color and shape and add to product differentiation. Roberta Cook reviewed the impacts of organics and the relatively minor success of organics in the marketplace. Barry Goodwin reviewed research coordinating wheat milling qualities, prices, and the need for improved communication of milling qualities needs to the wheat breeders. Hill emphasized that product segregation based on economic quality characteristics will not occur unless economic advantage exists. Currently, wheat, corn, and soybean standards are based on historic measures of limited use to the processing industry, such as test weight and moisture content. Discussion of the needs for integration of grading standards and needs across commodities, countries, and disciplines from production to assist in legitimate product differentiation.

Foreign Agricultural and Development Assistance: Donor Nation Perspectives on Levels, Trends, Types, Objectives, and Outlook. Fred J. Ruppel (Texas A&M University) and Wade F. Gregory (The Pragma Corporation), coordinators, Gregory also presiding; Duane Acker and Howard Steele (OICD USDA), Barry E. Prentice (University of Manitoba), E. Wesley F. Peterson (University of Nebraska), Chi-Ming Hou and Tain-Jy Chen (Ching-Hua Institute, Taipai)
Foreign agricultural development assistance has recently been a topic of discussion among donor agencies, recipient countries, academics, and policy makers. The panel agreed that agricultural and rural development is important for overall economic growth and that better linkages with international research organizations, private sector entities, and multinationals would enhance effectiveness. U.S. bilateral development assistance should be increased and directed to agricultural and rural development activities in a prioritized (but broader) array of LDCs. Guiding principles for Canadian development assistance include putting poverty first, development as a priority, and working in partnership. About half of Canadian aid is bilaterals with approximately three-fourths going to Africa and Asia. Development assistance programs in European countries differ considerably as a result of different historical relationships with the third world. Humanitarian concerns dominate Swedish and German aid efforts. France emphasizes education in an effort to spread French civilization, while U.K. relations with the third world are largely commercial. Because of events in Eastern Europe, there is much uncertainty concerning the future of European assistance. Taiwan's aid program has a focus on technology transfer, with agricultural experts working directly with farmers in recipient countries. This hands-on approach can be strengthened by incorporating market incentives in the future.

National Farm Financial Standards: The Development and Potential Use by Educators and Researchers in Agricultural Finance. David Kohl (Virginia Polytechnic Institute and State University, moderator; Freddie L. Barnard (Purdue University), James M. McGrann and Danny Klinefelter (Texas A&M University)
The Agricultural Bankers Executive Committee of the American Bankers Association (ABA) organized the Farm Financial Standards Task Force in 1989. This ABA task force of over fifty professionals from all aspects of agricultural finance have prepared, through consensus of opinion, a set of farm financial standards for agriculture. Members of the task force described recommended standards and suggested how they can be used in agricultural finance education and research activity. An effort to develop a national data base was described. Adoption of the standards as well as their incorporation into educational programs by land grant faculty are viewed as keys to success in their use in agriculture. Their use could have a very important long-term impact on financial performance documentation, analysis, and formulation of a national farm financial performance data base.

Agriculture, Technology, and Society. Gene F. Summers (University of Wisconsin, president, Rural Sociological Society [RSS]), organizer; Frederick H. Buttell (Cornell University, RSS president-elect), moderator; Don Dillman (Washington State University), Martin Kenney (University of California, Davis), and Linda Reif Labao (Ohio State University)
Dillman stressed that rural development specialists tend to ignore the opportunities of, and problems posed by, modern information technology for the development of rural regions and communities. Information technology can contribute to rural development by enabling service-information industries to locate far from metropolitan areas, but many rural communities lack access to digital telephone facilities essential to attract these industries. Kenney noted that there is a growing Japanese investment in manufacturing industries and in farm and agribusiness operations in U.S. rural areas and that the technologies and management practices employed in Japanese-owned businesses are already beginning to make a major impact on several U.S. rural regions. Lobao summarized the past several decades of rural sociological scholarship on the impacts of farm structural changes on rural communities and their possible implications for agricultural economics research. She noted that these studies, while conclusive in many respects, have almost totally ignored gender relations as a factor that shapes these effects and which is in itself affectd by shifts in agricultural organization and technology.

Toward Resolution of Data Access Conflicts. Edward I. Reinsel (ERS USDA), organizer; Douglas L. Young (Washington State University), Charles E. Caudill (NASS USDA), George T. Duncan (Carnegie-Mellon University)
The viability of our economy and functioning of our society can be enhanced by sharing available information. To ease replication, foster an attitude of openness, and insure honesty, several social science journals now require access to methods and data underlying reported research. Problems arise when legitimate information needs conflict with values and rules concerning the privacy of individuals. This symposium explored the nature of data access problems and searched for ways to lessen conflict. Young described how the Western Agricultural Economics Association policy on data access has worked and noted unresolved areas of tension. Caudill explained the NASS confidentiality procedures, publication policies, and options for data-sharing access. He discussed means of broadening data use including sta-

tistical or research enclaves, informed consent of survey respondents, artificial or masked microdata sets, and research fellowships. Duncan discussed progress to date on a major panel study by the Committee on National Statistics concerning confidentiality and data access. He discussed earlier work, outlined goals for the study, and described procedures being used.

Critical Economic Issues in Aquaculture Development. David Liao (South Carolina Marine Resources Center), organizer and moderator; Ken Roberts (Louisiana State University), organizer; Alan Kenney (British Columbia Salmon Farmer Association), Wade Griffin (Texas A&M University), Upton Hatch (Auburn University), Ivar Strand (University of Maryland), James Anderson (University of Rhode Island), Richard Johnston (Oregon State University)

The increasing consumer demand for seafood products, particularly in North America, has stimulated the tremendous interest in development of aquaculture industry in recent years. This symposium examined current economic issues related to aquaculture development. Kenney discussed economic issues facing the Canadian salmon-farming industry. Griffin reported that management is the major factor inhibiting the growth of shrimp aquaculture in the United States. According to Hutch, catfish price stability and product image are critical issues in catfish aquaculture. Strand focused on policy issues in oyster aquaculture in Virginia and Maryland. Anderson examined international trade issues related to aquacultural products. Johnston's summary remarks concentrated on future directions for economic research.

Comparability of International Data on Agricultural Outputs and Inputs. Susan Capalbo (Montana State University) and C. Ed Overton (ERS USDA) organizers; Anwarul Hoque (ERS USDA), moderator; Michael Denny (University of Toronto), Klaus Frohberg (OECD), Eldon Ball (ERS USDA), C. Ed Overton (ERS USDA)

The importance of trade to most agricultural sectors and the related issue of competitiveness have highlighted the need for comprehensive and consistent country-level data. The symposium examined the issue of data requirements for international analyses. Basic data—prices and quantities of agricultural outputs and inputs—are either collected in such a manner which does not facilitate intercountry comparisons or is not collected at all. Frohberg and Ball, both users of agricultural data, provided information on data sets. Frohberg focused on the EUROSTAT and SPEL data bases and suggested that information used for calculating PSE's and CSE's should be made public. He also indicated a need for comparable EC data on the level of policy instruments. Ball discussed his efforts to create a U.S./EC data set for econometric uses and productivity accounting. Participants also discussed general collection guidelines which may improve the usefulness of ongoing series, and political and institutional barriers for altering collection procedures. Denny offered suggestions for minor changes drawing on his data-collection experience in other sectors. Overton discussed the need for better communication between users and collectors, noting the costs involved in initiating major changes. He ended on an optimistic note: there is a formal mechanism within the UN and FAO which solicits proposals to initiate new data series or modify existing procedures. Such a mechanism should be exploited!

Comparative Analyses of Food Demand/Consumption and Agricultural Stucture/Supply in the United States and Japan. Rueben C. Buse (University of Wisconsin), moderator; Wen S. Chern (Ohio State University), Naraomi Imamura (University of Tokyo), Hiroyuki Arayama (Nagoya University), Luther Tweeten (Ohio State University), Masaru Morishima (University of Tokyo), Mitsuhiro Nakagawa (National Research Institute of Agricultural Economics, Tokyo), and Benjamin Senauer (University of Minnesota)

The joint U.S.-Japan research project represents a consortium of thirteen universities in the U.S. and seven universities and research institutions in Japan. Chern provided an overview on objectives and research design. Imamura pointed out the difficulties in achieving the structural reform of paddy-rice production because of small farm size and high land price in Japan. Tweeten argued that a rich nation can afford almost any agricultural structure. Public policy is capable of shaping that structure, but costs can exceed benefits of alternatives. Morishima indicated that Japanese food consumption has been shifting toward the diet pattern of western countries, i.e., increasing meat consumption and decreasing grain consumption. Senauer noted that increasing health concerns and changes in demographic variables have had significant impacts on food consumption, notably decreasing consumption of red meat in the United States. The panel also discussed the benefits of the joint project.

Future Directions of Farm Management. Jean-Paul Chavas (University of Wisconsin), moderator; Glenn Johnson (Michigan State University), George Casler (Cornell University), Arne Hallam (Iowa State University), Steve Sonka (University of Illinois)

The American Agricultural Economics Association has its roots in farm management in the early 1900s. Since then, the AAEA has diversified its scope to address economic issues going far beyond the farm-gate. In the process, the relative importance of farm management has greatly diminished over the last few decades. This symposium examined the current state of farm management and tried to anticipate possible directions for future developments. Glenn Johnson

provided an historical review of the evolution of farm management, its mission and its approach to the analysis of decision making. George Casler discussed the role of research, teaching, and extension. He suggested that teaching and extension in farm management outruns what has been done in research. Arne Hallam explored the linkages and the differences between farm management and production economics. Steve Sonka concluded by discussing the future prospects and challenges for farm management.

The Effect of Agriculture on Environmental Quality in Developed Countries: An International Perspective. Stephanie Mercier and Bengt Hyberg (ERS USDA) organizers; Stephanie Mercier, moderator; David Ervin and Bengt Hyberg (ERS USDA), Glenn Fox (University of Guelph), and Sean Pascoe (ABARE)

Recent concern over the environment and the potential contribution of agriculture to its degradation have led to questions on whether the agricultural policy structure in place in major agricultural countries tends to accelerate the degradation process. Pascoe divided U.S. programs into two categories: those that intensify input use and increase production (i.e., input subsidies and price supports), and those that tend to reduce production (ARP and CRP). Hyberg noted that in Australia the population is concentrated in urban centers away from agricultural production to such an extent that agricultural runoff affects mostly farmers. Ervin contrasted EC "green" fever and elaborate plans for conservation policies with the fact that only 6% of the EC agricultural budget is allocated to such activities. Fox found that most Canadian agricultural policies, while not necessarily leading to higher production, contribute to increased specialization both at the farm level and regionally, with unclear implications for the environment. Public awareness of this issue is increasing in developed countries, and the possibility was raised during discussion that environmentalism can be characterized as a luxury good, limited to populations where sufficient income and leisure time exist to permit individuals to notice and protest declines in environmental quality.

The Changing Role of Extension Economists in the 1990s. Gary Fairchild (University of Florida), moderator; Karen Klonsky (University of California, Davis), Damona Doye (Oklahoma State University), Otto Doering and George Patrick, (Purdue University), David Lambert (University of Nevada, Reno), Robert Christensen (University of Massachusetts), Fred Woods (Extension Service USDA), and Tim Wallace (University of California, Berkeley), summarist

Extension economists in the 1990s will be confronted not only with changing problems and issues but also pressure for interdisciplinary involvement, increased applied research, changing and expanding audiences, and potential funding limitations. The symposium focused on the implications of these trends by examining policy and program directions for the decade ahead. Klonsky and Doye discussed the role of extension economists in interdisciplinary and multidisciplinary research by noting the increasing complexity of science and the need to help audiences understand and interpret research results, as well as the impact of issues-based programming on traditional discipline-based programs. Doering and Patrick discussed the role of extension economists in applied research in terms of relationships with research economists, impacts on educational program delivery, and the need to generate additional resources. Lambert outlined challenges associated with incorporation of new problems and issues in extension program delivery in terms of new audiences and new techniques. Christensen and Woods discussed the challenge of funding a changing extension commitment. They noted the changes in federal, state, and county funding for extension and the increasing need for competitive and specialized grants. Wallace admonished the symposium participants for plowing old ground and called for a more futuristic focus.

North-Central Region Survey of Farm Operators and Spouses: Long-Term Adjustments Resulting from the Farm Crisis. Freddie Barnard (Purdue University), organizer; William Saupe (University of Wisconsin), moderator; Peter Korsching (Iowa State University), Larry Leistritz (North Dakota State University), Linda Lobao (Ohio State University), Arlo Biere (Kansas State University), Colletta Moser (Michigan State University), and Kent Olson (University of Minnesota)

Public attention has focused on the severity of the farm crisis at the national and state levels, but until now little scientific inquiry has been directed at the long-term effects of farm financial stress. Little is known about how economic hardship has affected long-term adjustments in farm operations, family functioning and individual well-being and how adjustments may differ in a sparsely populated versus an industrialized state. North-central region researchers collected comparative data on farm operations across the twelve states to determine adjustments as a result of farm financial stress and prospects for further economic and institutional changes. Korsching discussed the organization and implementation of this twelve-state regional study. Leistritz and Lobao compared findings for a sparsely populated state (North Dakota) to findings for an industrialized state (Ohio). Finally, differences in those states and other states in the region were discussed by Biere, Moser, and Olson.

Applications of Input-output Analysis to Agricultural and Rural Research—Problems and Prospects. Ron Shaffer (University of Wisconsin), moderator; Mark Planting (BEA USDC), David Holland (Washington State University), Mark

Henry (Clemson University), and Chinkook Lee (ERS USDA)
The symposium addressed four issues pertinent to using input-output (I-O) analysis in agricultural and rural research. Mark Planting, the economist with final responsibility for constructing the official 1982 U.S. table, addressed table data details and accuracy of the U.S. I-O table. David Holland dealt with using an I-O modeling framework to analyze structural change. He reviewed decomposition models for determining the sources of economic growth and discussed applications of the 1982 data. Mark Henry then addressed the experiences of using national I-O tables for rural and regional analysis. He also discussed constructing regional I-O tables from national tables and the usefulness of 1982 national I-O tables in rural and regional research. Chinkook Lee discussed the incorporation of the agricultural sectors into the U.S. I-O table.

Pitfalls and Rewards of Theoretical and Applied Research: Implications for Young Professionals. Catharine Lemieux (Indiana State University), moderator; Ronald Knutson (Texas A&M University), Cleve Willis (University of Massachusetts), and Kenneth Farrell (University of California)
Changes in funding priorities and an increasing emphasis on problem-oriented research are altering the research climate in the profession. An extension economist, department chair, and system vice-president addressed these issues and offered advice to young professionals. The three agreed that well-conceived and executed research will be rewarded whether it is applied or theoretical. Both Knutson and Willis felt it was important to select real problems and not "tinker at the margins" or become technique oriented in a research program. The need to develop a commodity or functional area expertise was cited as critical by Knutson. Knutson also recommended young professionals collaborate with other successful economists and seek a clientele of support outside the profession. However, both Knutson and Willis cautioned against doing consulting prior to tenure. Willis recommended interdisciplinary research saying, "If done sparingly it can increase funding, productivity, and publishing opportunities." However, Farrell emphasized the necessity of establishing disciplinary credentials and cautioned against engaging in interdisciplinary research prior to tenure. He suggested that new structures such as interdisciplinary research institutes outside the control of individual departments may be needed to address multidisciplinary issues. All agreed that their comments were aimed at describing the situation as it currently exists, not as what is optimal.

Use of Crop Simulation Models for Economic Analysis: Potential and Limitations. Robert O. Burton, Jr. (Kansas State University), moderator; Paul T. Dyke (Texas Agricultural Experiment Station, Temple), William G. Boggess (University of Florida), Ronald D. Lacewell and James W. Mjelde (Texas A&M University)
Numerous analyses performed by agricultural economists require crop production data. Crop simulation may be used to fill data gaps quickly and inexpensively relative to other data-gathering strategies. This symposium brought together agricultural economists who have had a wide range of experiences with crop simulation models to discuss potential and limitations. Dyke summarized their development, operation, and use. Boggess presented numerous uses in policy and nonfarm analyses. Lacewell discussed uses in farm management research. Mjelde focused on multiple models and questions users should consider. Burton summarized: (*a*) crop simulation models are daily (or less) time-step production functions; (*b*) they use climate, soil, plant growth, tillage, and management data to simulate physical, chemical, and biological processes; (*c*) they provide data under conditions that have not been observed; (*d*) they have been widely used. Subsequent discussion focused on validation and revealed the expectation of increasing use of crop simulation models.

Human Capital Topics Demanding Attention: A Canada/U.S. Comparison. Ray Bollman (Statistics Canada), organizer; Robert D. Emerson (University of Florida), moderator; Rich Barichello (University of British Columbia), Dan Sumner (USDA and North Carolina State University)
The primary areas of application of human capital over the past thirty-five years have been on schooling, productivity, and decision making, effects on output mix and quality, and management techniques. Although this research is highly relevant for the problems facing agricultural and rural areas, it was recognized that human capital research is not high on the agenda of any policy makers. Examples of problems toward which a human capital policy could contribute are substituting for farm programs, compensating for adverse trade effects, and facilitating the movement of labor out of agriculture. A number of topics were suggested for research attention on human capital. Among these were (*a*) the supply of human capital to agriculture, (*b*) the role of human capital in economic growth and international competitiveness, (*c*) the effect of human capital on farm size via speeding the adjustment to optimal size, (*d*) mobility out of farm labor markets, and (*e*) greater attention to education rather than just age and experience in explaining the effect of human capital. A necessary prerequisite to improving the human capital research base is improved data sets pertaining to human capital for rural areas.

Alternative Rural Development Perspectives. Ron Shaffer (University of Wisconsin), moderator; Amy Glasmier and Niles Hansen (University of Texas),

William J. Coffey (University of Quebec at Montreal), Susan Christopherson (Cornell University)
Rural development activities by researchers have been challenged by events of the 1980s and the limitation of traditional approaches. Four speakers from outside the association were invited to provide alternative perspectives on prospects for rural areas. Glasmier presented an overview of performance patterns in the rural economy relative to urban areas. Rural area researchers are urged to pay greater attention to international events, industrial structure and analysis, and corporate strategies. Hansen examined central issues in growth center theory relevant to current rural economic development concerns in the United States. The case of peripheral Jutland in Denmark was examined as a recent rural industrialization case study. Central government policies were found to have relatively little impact, while local cultural character played a key role. Coffey presented a framework for the analysis and utilization of a local development approach. Several guiding principles for local economic development were offered. (*a*) High priority should be given to human and information infrastructure. (*b*) Initiatives should respond more to market opportunities. (*c*) A diverse array of projects should be pursued. Christopherson examined rural development implications of flexibly specialized firms, industrial districts, new work patterns, and restructuring of service industries for rural areas. Trends in each of these areas are expected to present challenges for economic development efforts in rural areas.

Innovative Extension Education Delivery Methods—The Issues. Dean Baldwin (Ohio State University), Gerry Campbell (University of Wisconsin), and Lee Meyer (University of Kentucky), organizers; Dean Baldwin, moderator; Gerry Campbell, Terry Gibson (University of Wisconsin), Henry Bahn (ES USDA), Lee Meyer
Innovative technologies can complement extension education programs. The symposium provided an opportunity for the discussion of issues including educational effectiveness, parochialism, funding, training, and support needs. Campbell focused on the impacts on curricula and support. Gibson (participating via teleconference) discussed approaches to distance education and the learners' needs. Bahn discussed the implications for national programs. Meyer summarized evaluation approaches and results of distance education efforts among nonagricultural student groups. As part of the symposium, surveys were conducted before the conference among ag. economists and during the symposium among those attending. The same three topics were of highest interest to both groups: (*a*) concern about actual effectiveness, (*b*) the impact of parochialism on adoption and use of the delivery methods, and (*c*) interest in evaluation techniques, results, and use. Discussion focused on these three points, although there was also considerable debate about extension programs meeting "the market test" and the need for investment in human capital.

The Canadian Agricultural Policy Review: An Update. Ray Bollman (Statistics Canada), organizer; Garth Coffin (McGill University), moderator; Doug Hedley (Agriculture Canada), Ken Rosaasen (University of Saskatchewan), and Roger Hughes (British Columbia Ministry of Agriculture and Fisheries)
The Canadian government is in the midst of the most comprehensive review of agricultural policy in at least twenty years. Some fourteen task forces, involving more than 300 farm and industry leaders, academics and government officials, are preparing recommendations for the Minister of Agriculture on issues relating to market and trade development, farm finance and management, income safety nets, supply management in dairy and poultry, transportation policy, food quality, sustainable agriculture, and other topics. Hedley presented the background and rationale for the policy review and the process underway. The need for review is driven by changing consumer demands, increasingly competitive world trade, rapid technological change, increasing environmental concerns, and the need to maintain Canada's reputation as a supplier of safe and nutritious food. The "four pillars" or principles guiding this review are (*a*) increased market orientation, (*b*) increased self-reliance of farmers, (*c*) national policy which recognizes regional diversity and (*d*) environmental sustainability.

The process responds to long-standing demands of farm and industry groups to have more involvement in policy decisions. Rosaasen noted the division of regional interests between domestic and export market orientation and questioned where adjustment should occur and whether this process could be expected to recommend major change. Hughes reinforced the skepticism of process by questioning the consistency of an apparent emphasis on income safety nets on one hand with the need for change on the other.

Rural Governments in Financial Crisis. David Zimet, presiding (University of Florida), Susan White (National Association of Counties), Michael Hattery (Cornell University), David Chicoine (University of Illinois), Bruce Weber (Oregon State University)
Recent changes in federal aid, termination of revenue sharing, unfunded federal and state mandates, and declining tax bases have created financial burdens on local governments. Zimet and White reviewed the history of federal tax codes affecting tax-exempt bonds and how the federal fiscal crisis adversely affects that market. They contended that trends toward bond pooling by rural governments and lease financing will accelerate. Hattery stated ways to improve local efficiency include yielding greater fiscal and institutional flexibility to local governments, increased use

of technology to improve links among local governments and between them, and technical expertise. Chicoine noted that rural governments spend 25% more per capita on operating expenses than do urban governments. He stated that county governments act as agents for higher levels of government to constituents and as independent governments responding to constituent needs. Weber described the decline in federal support. He indicated local governments have lost proportionately more in funding than state governments. He noted that special districts have been created to support specific activities.

Undergraduate Curriculum Review: Translating Review into Curriculum Change in Agricultural Economics. Carl Zulauf, (Ohio State University), moderator; Dale Dahl (University of Minnesota), Larry Conner (Michigan State University), Bernard Erven, (Ohio State University)

The University of Minnesota, Michigan State University, and Ohio State University have reviewed and revised their undergraduate programs in light of continuing national concern about undergraduate education. Similarities and differences in the experiences of these three departments were presented in this symposium. Implications for the profession were also drawn. Key similarities among the three departments were a clearly defined mission for undergraduate education, an opportunistic approach to review which led to reform in curricula rather than just minor changes, careful attention to both process and content in curricular revision, no major called agricultural economics, and the importance of relationships with colleges of business. Key differences included the number and content of new majors, role of service courses, use of the core course concept, and business school-type courses in agricultural economics. Implications for the profession included the need for clarification of the mission for undergraduate education, distinguishing between professional and disciplinary education, role of business courses, job descriptions for new faculty positions, and the need for teaching materials to support the new curricula.

Initiatives and the Funding Process for Rural Social Science and Extension. Ronald C. Wimberley (North Carolina State University), organizer; James J. Zuiches (Washington State University), Kenneth R. Farrell (University of California), and Russell C. Youmans (Western Rural Development Center)

This panel provided information and updates on the social science research and funding initiatives that have been advanced in the past year. The panelists served this effort through ESCOP and National Association of State Universities and Land Grant Colleges' (NASULGC) Division of Agriculture. Efforts through USDA and NASULGC continue to unfold during this congressional session. These include work on the farm bill plus research and extension appropriations, which await a Senate-House compromise, for rural research in the National Research Initiative for Research in Agriculture, Food, and Environment. Farrell explained how research initiatives develop through regional experiment station directors in NASULGC. He challenged social scientists to influence this process at various stages. Youmans pointed out a difference in the experiment station agenda, which concentrates more on physical agricultural issues, and the extension agenda, which concentrates on the broader issues facing farm and rural people. Someone added that social scientists should take issues and findings to research administrators to show the broader role.

The Conservation Reserve Porgram after the Contracts Expire: What Then? Richard T. Clark, (University of Nebraska), co-organizer and moderator; James B. Johnson (Montana State University), co-organizer and presenter; Michael R. Dicks (Oklahoma State University), Steven B. Kraft (Southern Illinois University), C. Robert Taylor (Auburn University), and Gary A. Margheim (SCS USDA)

CRP has removed nearly 34 million acres from production since 1986. The ten-year contracts will begin expiring in 1996, and the land will become eligible for cropping. Johnson, Dicks, Kraft, and Taylor provided regional estimates of the proportions of CRP that might return to crop production. Estimates ranged from a low of 10% in the southeast to 80% in the southern plains. Panelists expected a total of 19 million acres to return to crop production. Margheim, using a national rather than regional approach, estimated that from 14 to 16 million acres would remain in conservation use. Taylor, using AGSIM and related econometric simulation models projected the impacts of CRP lands returning to production on crop prices, acreages, and net farm income. Expected price reductions would range from 1% to 2% for livestock to 6% to 7% for hay. These reductions were below a baseline situation—the continuation of the 1985 Food Security Act provisions. U.S. net farm income was projected to decline about 10% if 19 million acres return to crop production. Discussion focused on policy options for maintaining selected lands in conservation cover. Options debated included targeting of certain land classes for compensated retention, payment of contract holders for differences in return to land between crop and livestock production, extending contracts to fifteen years and stiffening requirements for conservation compliance.

Black Farmers: Trends, Problems, and Prospects. Surendra P. Singh (Tennessee State University), organizer; Christina H. Gladwin (University of Florida), moderator; F. S. Bagi (North Carolina A&T University), Tesfa G. Gebremedhin (West Virginia University), Richard D. Robbins (North Carolina A&T University), Surendra P. Singh and Sammy Comer (Tennessee State University)

In spite of the attention given by the government and private sources, the crisis facing black farm operators continues to escalate. This symposium discussed and assessed from a variety of perspectives, conditions and problems of black farm operators. Gladwin introduced the topic by pointing out some relevant statistics and the importance of small farms for rural communities in general. Singh presented briefly the trends and characteristics of black farmers. He also pointed out the major problems facing black farmers. Their problems are grave, and they are broader than economic adjustment within the agricultural sector alone. Bagi discussed the relative efficiencies and resources used on black and white farms. He concluded from a study in Tennessee that there were no significant differences in technical inefficiencies on black and white farms. Gebremedhin discussed present policies and their implications for black-operated farms. He emphasized various appropriate public policy measures to help black farm operators. Robbins discussed and presented a case study on how land grant institutions can help small black farm operators by showing them how to manage their enterprises more efficiently. Audience participation was great, and their comments included reports on land loss, alternative enterprises, off-farm work, and programs to help black farm operators. It was suggested that the heterogenous nature of black farm operators, intrinsic value of land, and small size of black-owned parcels be recognized and considered in developing future programs and policies to assist black farm operators.

Rural Infrastructure Issues: Roles of Researchers and Extension Workers in the 1990s. John Halstead (University of New Hampshire), moderator; Mark S. Henry (Clemson University), Gerald A. Doeksen (Oklahoma State University), and Danny Klinefelter (Texas A&M)

Rural infrastructure has been identified by the Cooperative Extension Service and experiment station leadership as a priority issue. This resulted from the fact that rural infrastructure (*a*) is in poor condition, (*b*) is poorly funded (federal government is decreasing funding), and (*c*) influences economic growth and development. This symposium examined what extension and research professionals can do to provide assistance to local decision makers. Henry suggested research to measure the relationship between infrastructure and economic growth, on how to use the GIS system in infrastructure analysis and to continue budgeting research which includes funding alternatives. Issues of equity and efficiency need to be addressed. Doeksen identified extension areas as community leadership development, information dissemination, technical information for specific projects, and overall capital improvement planning. Klinefelter reviewed a document published by the Southern Rural Development Center which discusses case studies of innovative infrastructure financing and delivery systems. The publication presents case studies on transportation, business incubators, emergency medical services, fire, industrial sites, recreation, education, health, water and sewer, roads and bridges, social services, and solid waste. A copy can be obtained from the Southern Rural Development Center.

New Productivity Measurement Research. Roger K. Conway (ERS USDA), organizer; Frank Gollop (Boston College), moderator; Eldon Ball (ERS USDA), P. A. V. B. Swamy (Federal Research Board), Rolf Färe (Southern Illinois University), Jet Yee (ERS USDA), Erwin Diewert (University of British Columbia), Wallace Huffman (Iowa State University), and Dan Primont (Southern Illinois University)

Ball and Conway described the new ERA Törnqvist productivity indices created in response to AAEA task force recommendations. These indices are quality adjusted and will provide a detailed data base suitable for studies of producer behavior. Swamy indicated a method to separate scale from technology changes as well as forecast productivity changes using stochastic coefficients. Diewert cautioned that inflation effects were not accounted for and coefficient restrictions were needed to get theoretically valid estimates. Swamy agreed and indicated restricted estimates of his method could be obtained. Malmquist indices offer many virtues according to Färe, such as the ability to separate changes in performance from changes in the frontier of technology. Adjusting for capacity utilization, Yee found agricultural productivity growth declined around 18% between 1949–80. Self-employed labor was in surplus throughout, while capital was in shortage until 1980. Primont observed each method seeks to decompose the sources of growth. Huffman called for greater resources directed to data development with land grant universities assisting the process.

Potential Role of the Service Sector in Rural Economies. Stephen M. Smith, (Pennsylvania State University), organizer and moderator; Frank M. Goode (Pennsylvania State University), Cathy D. Kassab (Pennsylvania State University), Shirley L. Porterfield (ERS USDA), Glen C. Pulver (University of Wisconsin)

The purpose was to present and discuss issues and evidence related to the effects and role of the service sector in rural economic growth. Goode focused on the causal versus passive role of services in economic growth. Evidence for Northeast communities showed that manufacturing growth was more likely in communities with a complex versus a simple service structure. Porterfield discussed the nature of producer services growth in rural counties. National county-level data showed that producer services grew rapidly in nonmetro counties with highly educated labor that were regional centers adjacent to metro counties, and that such growth was more dependent on manufacturing growth than in metro counties. Kassab considered the effect of growing rural service employ-

ment on incomes. For the more remote rural areas, both low and high wage services led to an increase in middle income groups. In centrally located communities, however, service growth led to a more bipolarized income distribution. Pulver summed up by focusing on needed research, emphasizing classical versus nontraditional location factors for specific service sectors, particularly those amenable to policy manipulation, and wage and income distribution impacts. Audience discussion centered on measurement issues and suggested areas for future research.

A National Policy of "No Net Loss" of Wetlands: What do Agricultural Economists Have to Contribute? Jon Goldstein (U.S. Department of the Interior), moderator; Ralph E. Heimlich (USDA), Peter J. Parks (Duke University), John C. Bergstrom (University of Georgia), and Leonard Shabman (Virginia Polytechnic University)
Most wetlands lost recently were converted for agricultural production. President Bush proposed "No Net Loss" as a national goal, meaning that restoring wetlands must complement conserving wetlands to offset unavoidable losses. This symposium explored how "No Net Loss" might operate and the economist's role in developing this policy. Heimlich traced wetland policy evolution. He concluded that proposals to restore wetlands in the 1990 farm bill and the "No Net Loss" task force are a logical next step. Parks reviewed normative and positive approaches to estimate costs of acquiring wetland easements. Estimating landowners' participation in easement programs and participating acreage is more difficult than estimating wetland opportunity costs. Bergstrom stressed that economists urgently need to extend site-specific benefit studies to regional evaluation models (REMS) for more general policy development. Local wetland benefit studies are still needed to help assess programs for conserving and restoring wetlands. Shabman suggested that economists' experience in designing institutions that rely upon financial incentives rather than command and control regulation can benefit wetland programs to achieve no net loss. Wetland development fees based on development value rather than wetland value could help rationalize the permitting process.

Emerging Nonparametric Techniques for Applied Production Analysis. Tom Cox (University of Wisconsin), moderator; Jean-Paul Chavas (University of Wisconsin), Hongil Lim and C. Richard Shumway (Texas A&M University), Alfons Weersink (University of Guelph), Giancarlo Moschini (Iowa State University)
Nonparametric techniques facilitate economic analysis under less restrictive maintained hypotheses than commonly implied by traditional parametric approaches. In particular, these techniques do not require the ad hoc, a priori, parametric specification of choice functions (such as supply and demand, profit, cost, nor production functions). Several variations on this nonparametric theme have been applied to topics in agricultural economics. One major variation, popularized by Färe, extends Farrell's seminal work on technical efficiency measurement using linear programming to estimate nonparametric production frontiers. A second major variation derives from Varian's use of "revealed preference" analysis to generate sets of testable inequalities implied by alternative axioms of producer behavior. A third major theme concerns kernel estimation of nonparametric density functions to generate nonparametric and/or hybrid semiparametric specifications. The symposium summarized the current use of these emerging nonparametric techniques for applied production analysis with emphasis on the strengths and weaknesses of these emerging techniques relative to more traditional approaches for applied production analysis. Chavas provided an insightful, integrative overview/contrast of the Färe and Varian approaches. Lim and Shumway, Weersink, and Moschini then contrasted the strengths and weaknesses of the Varian, Färe, and kernel estimation approaches relative to traditional parametric alternatives, respectively.

Base Flexibility and Related Options for Reducing Price Distortions for Input Use. Clayton Ogg (U.S. EPA), moderator; David Zilberman (University of California), Stanley Johnson (Iowa State University), David Ervin with Ian McCormick and Kazim Konyar (ERS USDA)
Reducing price distortions and base flexibility are central to recent farm policy debates. Price distortions that encourage input use undermine farm program goals and add to environmental problems. This symposium examined how distortions occur, their extent or seriousness, and proposed remedies available within current farm program structures. Zilberman found that agricultural and resource policies have been inconsistent, although some progress has been made in addressing this problem. Farming activities have been conducted in environmentally sensitive areas, while agricultural production capacities in less-sensitive areas have been idle. Coordination of commodity and resource programs will require interagency management of agricultural resource policy, a unified research effort to address and assess efficiency, and equity and environmental consideration of alternative policies. Johnson used input demand and output supply functions to evaluate trade-offs for commodity program parameters, emphasizing impacts for distortions. Results show opportunities for more efficient design of programs and improved targeting of benefits. Ervin, McCormick, and Konyar find effects of planting flexibility very sensitive to design features: for example, which crops are permissible on bases and level of flexibility will determine resource use and environmental impacts.

China's Agricultural Trade in the 1980s and Prospects for the 1990s. Wen S. Chern (Ohio State University), moderator; Shi Ru (International Trade Research Institute, MOFERT, China), Francis C. Tuan (ERS USDA), Torng-Chuang Wu (Council of Agriculture, Taiwan), Joseph Chai (University of Hong Kong), Y. Y. Kueh (MacQuaire University, Australia), Niu Ruofeng (Research Institute of Agricultural Economics, MINAG, China), and Hsi-Huang Chen (National Taiwan University)
Chinese agricultural trade, both mainland and Taiwan, changed rapidly in the 1980s. In mainland China, institutional and other economic reforms have enhanced agricultural production and increased agricultural commodity exports in the 1980s. Taiwan's liberalization of agricultural trade rapidly altered its trade structure between Taiwan and the United States and between Taiwan and many other countries. Shi and Tuan summarized China's agricultural trade development and discussed prospects. Wu stated Taiwan's agricultural trade growth and future policies. Chai and Kueh analyzed major factors affecting China's agricultural trade. The symposium concluded with Niu and Chen's comments on the above presentation.

What, If Anything, Can the Fellows Contribute to the Profession? R. J. Hildreth (Farm Foundation), moderator; Wayne D. Rasmussen (ERS USDA, retired), Otto Doering (Purdue University), and Paul Barkley (Washington State University)
A supply exists of fellows who are willing to try and help improve the profession. However, it is unclear whether a demand exists for such services. This symposium explored the matching of supply and demand through activities to be sponsored by the AAEA Fellow's Activity Committee. Rasmussen presented a historical foundation for tomorrow's profession. Otto Doering, chairman of the Adaptive Planning Committee, discussed the supply and demand sides of the question and presented possible undertakings for the Committee from the perspective of the Adaptive Planning Committee's deliberations. Barkley also discussed the supply and demand issue as well as possible activities of the Fellow's Committee from the perspective of activities planned and conducted by the Professional Activities Committee. Discussion and interaction with the audience was a major aspect of the symposium. The outcome of the symposium is a major input to planning by the Fellow's Activities Committee.

Software Packages for Statistics and Econometrics: A Case Study—SHAZAM. Oral Capps, Jr., (Texas A&M University), moderator; Kenneth J. White (University of British Columbia), Donna Wang (University of British Columbia), Diana Whistler (University of British Columbia), Doug Pearce (University of British Columbia), Jeffrey Perloff (University of California, Berkeley), Quentin Grafton (University of British Columbia), and Meredith Scantlen (University of British Columbia)
Software packages for statistics and econometrics are growing in number. The list includes SAS, RATS, TSP, ESP, and SHAZAM. Without much investment in time, it is difficult for quantitative analysts to make decisions concerning which package(s) to use for research purposes. Also, it is generally not possible for researchers to interact with software developers. This symposium centered attention on SHAZAM. White provided a discussion of the development and description of this econometrics package. Others discussed possible upgrades of this package. Interaction took the form of suggestions to include upgrades or new procedures, to write special programs, and to improve existing routines. As well, symposium attendees were able to get "hands on" experience with the software package. This symposium was unique in that it permitted interactions between analysts and software developers.

Prioritizing Riparian Lands for Restoration, Including Wetlands and Stream Corridors. Peter Kuch, presiding (U.S. EPA), G. C. Van Kootan (University of British Columbia), Andrew Schmitz (University of California, Berkeley), Steven Lovejoy (Purdue University) and Clayton Ogg (U.S. EPA)
Priorities need to be established protecting wetlands and retiring croplands made eligible in the new U.S. farm bill proposals for "environmental reserve programs" (ERP). Van Kootan illustrates the key role that current farm support programs have had in depleting waterfowl habitat. This has occurred both because of the way benefits are determined and the fact that programs discourage animal husbandry. Schmitz notes however, that potholes impose added operating costs on the farmer in terms of machine operating time and hassle. He also points out that once land has been converted to grainland, it usually does not return to grassland regardless of relative prices. Lovejoy reports on work comparing the efficacy of various "structural type" approaches for reducing sedimentation damage. He finds targeted conversion of uplands produce the greatest reduction, but the targeting is very information intensive. Vegetative filter strips along watercourses proved to be almost as good and required a lot less information. Ogg notes that prioritizing farmers ERP bids to favor vegetative filter stips and wetland reserves represents an administrative challenge, as does coordination with state water quality plans. International cooperation to avoid price distorting policies will address the causes of wetland and other environmental losses, while furthering farmer objectives.

Conflicts in Food and Agricultural Policy. Kate Clancy (Syracuse University), organizer and pre-

senter; Carol Kramer (Resources for the Future), moderator and presenter; Jean Kinsey (University of Minnesota), and Katherine Reichelderfer (Resources for the Future)
Conflicts and complementarities among the various interests in agricultural and food policy are longstanding. However, new issues and proposed policy changes frequently highlight the conflicts without emphasizing the potential for complementarity. The areas covered in this symposium were selected critical conflicts among food safety, nutrition, food production and marketing, and environmental policies. Extensive audience discussion followed the presentations. Two main themes emerged. The first was the question of the jurisdictional level—state, federal, or international—at which regulatory standards should be set, and the appropriate role of public and private decision makers. A related concern was the appropriate combination of production, processing, and product standards and enforcement mechanisms. The case of organic certification nicely illustrates many of the issues. There was agreement that there is a need for better comprehension of complex issues involving different policy sets and their inherent conflicts, including the impact on production agriculture of changes in demand for nutrition, health and environmental amenities.

Economic Issues in Trade Disputes Over Agricultural Products. Erna van Duren (University of Guelph), organizer; Randy Wigle (Wilfrid Laurier University), moderator; Heather Meek (Agriculture Canada), Carol Goodloe (ERS USDA), James Rude (University of Guelph)
Canada applied more economic logic to settling countervailing duty disputes than the U.S. and is more consistent with the GATT Subsidies Code. However, both countries could improve the application of their countervailing duty law by basing the law on economic principle. Despite the fact that economic models are imperfect, can be based on different assumptions, and encompass a range of elasticities, they can focus on the correct issue, the impact of one country's subsidy on the welfare of another's producers, and what type and level of countervailing duty should be imposed to remove the injury. Economic studies of the hogs and port dispute (U.S. vs Canada) have led to remarkably similar types of results, despite the diversity of modelling approaches and specifications used. Canada and the U.S. apply their antidumping laws in a manner that, if applied with some ingenuity, makes it impossible to lose this type of case on a horticultural product.

The Food-Processing Sector: The Role of Economic Information to Facilitate Adjustment and Growth. Ray Bollman (Statistics Canada), organizer; Rebecca Lent (Université Laval), moderator; Howard Migie (Agriculture Canada), Tim Hazeldine (University of British Columbia), and Randy Westgren (Macdonald College of McGill University)
The Canadian federal government has initiated the first extensive agricultural policy review in two decades. A major player in this review is the food-processing industry. Economists can play a vital role in providing appropriate information to the private sector. Trade issues such as the import ban on margarine, the U.S. countervail on Canadian hog products, and cross-border shopping illustrate the consequences of different degrees of support and protection. Coloring restrictions on margarine in Ontario and Quebec, regulation of grain and oilseed freight rates, and producer domination of supply management institutions indicate that much of current regulation is based on a producer focus rather than on a broader industry focus. This emphasis may be modified through policy review. Research in the area of competitiveness is essential to understanding how to encourage more collaboration between firms without stifling rivalry. Traditional economic analysis is important and useful for answering specific policy questions, however more analysis of institutions and rent-seeking behavior is needed to consider these issues in a comprehensive way.

Preparing to Assess the Long-term Impact of Immigration Reform on Agriculture: Can We Build on the Early Indicators of Farmer and Worker Adjustment? Howard R. Rosenberg (University of California, Berkeley), organizer and moderator; Leo C. Polopolus (University of Florida), Robert G. Mason (Oregon State University), Jeffrey M. Perloff and Susan M. Gabbard (University of California), H. L. Goodwin (Texas A&M University), Shannon Hamm (Commission on Agricultural Workers)
Although Congress passed the Immigration Reform and Control Act of 1986 (IRCA) explicitly to control illegal immigration, various other effects of the law have been desired, feared, predicted, and perceived as emerging. Individual responses so far to IRCA's complex set of inducements and penalties only begin to form its long-term impact on agriculture. Polopolus described recent efforts to develop benchmark data about seasonal farm work force, wages, management practices, and labor market structure in Florida and analyzed simultaneous concerns about future labor surpluses and shortages. Mason observed that minimum wage raises and product market competition make highly productive illegal aliens increasingly preferable to local legal residents in Oregon harvests. Perloff reviewed national survey data showing very low rates of worker departure from agriculture in fiscal 1989, notably except for those employed by farm labor contractors. Goodwin reported employer adjustments in Texas ranging from provision of new fringe benefits and more use of FLCs to mechanization and cropping pattern changes, the lat-

ter related also to irrigation constraints. Hamm outlined research planned by the Commission on Agricultural Workers to meet its statutory charge. Interacting with other legal, natural resource, and market forces, IRCA calls attention to farm labor issues that will continue to present rich opportunities for research contributing to policy as well as theory. Complexity and sensitivity of studies in this field necessitate public support for collection of relevant time-series data.

Selected Papers

The Managerial Economics of Agribusiness Firms (Bryan W. Schurle, Kansas State University, presiding)

"Comparative Performances of Food-Processing Cooperatives and Investor-Owned Firms." Claudia Parliament (University of Minnesota) and Zvi Lerman (Hebrew University)
Financial performance of cooperatives and investor-owned firms in two food industries is compared over time. Contrary to expectations, cooperatives do not exhibit lower profitability, overinvestment in assets, or excessive borrowing. The difference in objectives between cooperatives and investor-owned firms is not reflected in their financial performance.

"Industry and Size Effects in Agricultural Cooperatives." Zvi Lerman (Hebrew University) and Claudia Parliament (University of Minnesota)
The analysis of financial data from 1970–87 reveals significant size and industry effects among forty-three agricultural cooperatives. Large regional cooperativies are more efficient in utilizing assets to generate sales, while small regional cooperatives have higher profit. Dairy cooperatives are the strongest performers, and food marketing cooperatives are weakest.

"Are Milk Assembly Costs Linear in Volume Only? Evidence from the Greater Ohio Milkshed Suggests That They Are Decidedly Nonlinear." Edward W. Gallagher (Federal Milk Market Administrator's Office, New York City), Cameron S. Thraen and Gary D. Schnitkey (Ohio State University)
A nontraditional multi-output cost function for milk haulers is estimated. Outputs are defined as (*a*) assembly miles, (*b*) transport miles, and (*c*) volume of milk hauled. Data from forty firms provide evidence that the cost function is not linear in any of the outputs.

"An Evaluation of Input Purchasing Behavior at Local Farm Supply Cooperatives." Marcus L. Hartley and Jim Cornelius (Oregon State University)
This study explores a model of purchasing behavior at farm supply cooperatives. Using a methodology of seemingly unrelated regressions, purchases of different farm inputs were estimated based on a set of highly correlated, often subjective, independent variables. Generally, these attitudinal variables were of limited significance in explaining patronage of cooperatives.

"Analysis of Compensation in Agribusiness: The Case of the Retail Fertilizer Industry." Bradley P. Martens and William J. Taylor (Virginia Polytechnic Institute and State University)
This analysis examines the determinants of compensation from both employee and firm perspectives. The findings indicated that experience, education, firm size, and form of ownership are the key determinants of compensation.

Selected Issues in Agricultural Management (Gregory M. Perry, Oregon State University, presiding)

"Dynamically Optimal Biannual Range Culling Decisions versus Culling When Open in the Southwest." Russell Tronstad and Russell Gum (University of Arizona)
Optimal range culling decisions are solved by considering the age of the cow, pregnancy state of the cow, and replacement-calf-slaughter price levels. Results indicate that annual profits can be increased by about $37.00 per year from following an optimal culling strategy instead of culling whenever the cow is open.

"Weather Forecast Information and Farm and Ranch Decision Making: Results of a Survey." Kevin P. McNew (North Carolina State University) and Harry P. Mapp (Oklahoma State University)
Surveys of farmers and ranchers identified weather information used in production, marketing, and management decisions across a diverse agricultural region. Timing of planting, harvesting, and pesticide applications were based on temperature, precipitation, relative humidity, and wind movement. Short-term forecasts were more important for timing decisions on diversified operations.

"Managing Timberlands for Profitability." John P. Dwyer, Ronald L. Plain, and William B. Kurtz (University of Missouri)
This research evaluates long-term effects of thinning and pruning on net present value of oak timber. Analyses indicate no significant differences in grade or value of lumber result from pruning. However, thinning was found to have a significant effect on the quantity, grade, and value of timber produced.

"A Cash Flow Approach to Land Affordability." Gregory D. Hanson (Pennsylvania State University) and John F. Jinkins (USDA ERS)
A land price affordability model is proposed as a leading indicator of land price changes. Patterned after a housing affordability index, the model comple-

ments econometric models of land markets. Results show increases in ability to cash flow land purchases since the mid-1980s. Land is slightly less affordable in 1990.

"An Economic Comparison of Subsurface Micro-irrigation with Center Pivot Sprinkler Irrigation for Row Crop Production." Darrell Bosch (Virginia Polytechnic Institute and State University), Norris L. Powell and F. Scott Wright (Tidewater Agricultural Experiment Station)
An economic comparison is made of center pivot sprinkler irrigation and subsurface micro-irrigation for a corn and soybean rotation. For smaller fields, micro-irrigation has lower per-acre investment costs and higher net returns. As field size increases, center pivot systems have lower per-acre investment costs and higher net returns.

The Economics of Nontraditional and Sustainable Agricultural Enterprises (Larry Van Tassell, University of Tennessee, presiding)

"The Economics of Meat Goat Enterprise for Small-Scale Producers." Tesfa G. Gebremedhin (West Virginia University)
A comparison of net present values, payback periods, and financial feasibility analysis were the methods used to determine the most profitable operation of small-scale meat goat production. A cash surplus, attributed to land, family labor, and management for three alternative investment systems, occurred at the end of the third year.

"Profitability of Alternative Farming Systems in Ohio." M. S. Diallo, D. L. Forster, F. J. Hitzhusen and M. T. Batte (Ohio State University)
Profitability measures (net farm income and return on assets) are related to several factors including low input farming practices. Results indicate that farm size and financial leverage are related to profitability. Low input practices, such as diversification, reduced fertilizer and chemical use, and legume based rotations, have negligible impacts.

"Does Sustainable Farming Pay: A Case Study." Kathleen M. Painter (Washington State University)
A well-publicized western wheat farm has produced competitive yields without commercial fertilizers and minimal pesticides over the past eight decades. Under crop prices and program provisions for 1986–89, however, the farm's green manure rotation earned net returns averaging 23% lower than a typical conventional rotation for this area.

"The Role of Crop Insurance in Reducing Pesticide Usage." Eli Feinerman (Hebrew University of Jerusalem), Joseph A. Herriges and Derald Holtkamp (Iowa State University)
This paper investigates the potential for crop insurance to serve as a tool for reducing pesticide usage by providing a substitute for the risk management benefits of pesticides. A representative farm simulation model is employed to consider the interaction of pesticide restrictions, crop insurance, and the federal commodity program.

"A Financial Simulation Analysis of Hybrid Striped Bass Production Stages from Hatchery to Market." F. F. Wirth, C. M. Gempesaw, II, J. R. Bacon, and G. F. Vaughn (University of Delaware)
An increasing number of farmers are diversifying and seeking alternative crops and farming systems. This study evaluates hybrid striped bass aquaculture as another source of farm income. Dynamic simulation and stochastic dominance are used to analyze the economics of four phases in hybrid striped bass production.

Conceptual Issues In Agricultural Management (Cole R. Gustafson, North Dakota State University, presiding)

"Efficiency Measures Using the Ray-Homothetic Function: A Multiperiod Analysis." David L. Neff, Philip Garcia, and Robert H. Hornbaker (University of Illinois)
Recent investigations provide mixed assessments of farm efficiency. This analysis examines a homogenous sample of farms over a six-year period and efficiency measures are found to increase with temporal aggregation. Stratification of the farms by size indicates that the ray-homothetic function attributes high-scale inefficiencies to larger farms.

"Multiple Objective and Nearly Optimal Solutions in Greenhouse Management." Cleve E. Willis and Michael S. Willis (University of Massachusetts)
A linear programming model of greenhouse decisions based on expected profit maximization is modified to generate noninferior solutions based on family labor savings and expected profit considerations. These solutions are contrasted with nearly optimal solutions generated by the HSJ procedures.

"The Simultaneous Optimization of Product Quality and Production Quantity." S. Andrew Starbird and Paul M. Thompson (Santa Clara University)
A general class of profit maximization problems which optimally allocate resources between product quality and production quantity is formulated and analyzed. Expected profit is expressed using a stochastic qual-

ity variable. Profit-maximizing conditions are derived for quality variables with a normal, exponential, and Weibull distribution. Rework and give-away costs are considered.

"A Conceptual Framework for the Management of Farm Businesses." Robert A. Milligan and Guy K. Hutt (Cornell University)
A comprehensive integrating conceptual framework for the management of farm businesses is developed. The framework, based on the management literature, emphasizes the management of people, including oneself, and the functions of the manager—planning, organizing, staffing, directing, and controlling. The framework is currently being used in research and extension programs.

"A Test of the Applicability of Strategic Management to Farm Management." K. Harling (Wilfrid Laurier University) and W. Paterson (University of Kentucky)
Strategic management has proven a useful conceptual approach for nonfarm business managers. In this paper, its applicability to farm management is tested using discriminant analysis. Successful farmers are found to think more strategically than less successful ones, suggesting that it can be a useful way of thinking about farm management.

Managing the Agricultural Business Under Uncertainty (Darrell Bosch, Virginia Polytechnic Institute and State University, presiding)

"Analyzing Risk-Income Performance with Adaptive versus Nonadaptive Enterprise Mix Decisions." Larry J. Held and Mark E. Schutt (University of Wyoming)
Risk-income benefits of revising a firm's enterprise mix in response to updated information is examined from the standpoint of historical income variability and frequency and amount of target loss. The impact of improved information on a firm's risk status appears to depend heavily upon the type of risk expression.

"Double-Cropping Soybeans into Traditional Crop Rotations Under Government Commodity Program Restrictions." Jayson K. Harper (Pennsylvania State University), Jeffery R. Williams and Robert O. Burton, Jr. (Kansas State University), Kenneth W. Kelley (Southeast Kansas Branch Experiment Station)
Six enterprise combinations, four with double-crop soybeans, were evaluated using stochastic dominance analysis assuming government program participation. Wheat and double-crop soybeans followed by full-season soybeans was the preferred rotation for all risk preference intervals analyzed. Sensitivity analysis showed that when constraints limit double cropping, combinations with less than maximum double-crop acres are preferred to those without doublecropping.

"Use of a Crop Simulation Model to Provide Long-term Data for Economic Analysis: The Case of Early Maturing Soybeans." Robert O. Burton, Jr., Guido van der Hoeven, and Allen M. Featherstone (Kansas State University), George V. Granade (Georgia Experiment Station)
A target MOTAD model is used to investigate incorporating early maturing soybeans into a crop farm in southeastern Kansas. A weather (WGEN) and crop simulation model (SOYGRO) are used to generate a long-term series of soybean yields. Results indicate that early maturing soybeans offer a risk-reducing diversification strategy.

"A Dynamic Analysis of Irrigation Technology Adoption in the Central High Plains." Raylon C. Earls and Daniel J. Bernado (Oklahoma State University)
A dynamic model is presented for determining the optimal temporal pattern of irrigation investment and water allocation for irrigators in the Central High Plains. The model is applied to a representative irrigated farm. Optimal investment strategies are shown to be sensitive to initial pump lift, energy price, and crop price expectations.

"Multiperiod Rangeland Investment Analysis with Safety-First Constraints and Uncertain Data." David K. Lambert and Thomas R. Harris (University of Nevada, Reno)
Impacts of crested wheatgrass seeding investments on ranch equity and income indicators are examined. Expected ending new worth is maximized subject to stochastic forage production and prices using multiperiod nonlenear programming with safety-first income constraints. Seedings are found to be beneficial by stabilizing forage supplies and permitting herd expansion.

Farm Management: Surveys, Perceptions, and Decision Making (Paul N. Wilson, University of Arizona, presiding)

"Friend or Foe? Farmer Perceptions of Biotechnology." J. E. Hobbs and W. A. Kerr (University of Calgary), K. K. Klein (University of Lethbridge, Alberta, Canada)
This paper is the result of a survey investigating the attitudes of western Canadian farmers towards two biotechnological products, Enfix-L and PB-50. Farmers were asked to rate both the importance and the performance of twenty-one attributes of the products. Soil depletion was found to be an important

concern to many farmers. Personal and environmental risks were less of a concern. Overall, it was found that the nonbiotechnical aspects of a product would prevail in purchasing decisions.

"Obtaining Management Profiles of Ontario Swine Producers Through Cluster Analysis." Alejandro Rosenberg and Calum G. Turvey (University of Guelph)
This paper develops managerial profiles of Ontario Swine Producers for extension use, using mail survey data and cluster analysis. Results indicate that there are four major discriminant variables which can be used to identify different classes of farmers. These management profiles can be used for targeted extension efforts.

"Preference for, and Accomplishment of, Farm Tasks by Farm Wives in Dona Ana County, New Mexico." Wilmer M. Harper and Rossana Alvarez de Ayala (New Mexico State University)
Wives are major participants in agricultural operations and management. If their tasks are unrecognized or undocumented, their labor contribution may be inadequately documented, leaving this resource unacknowledged and/or misallocated. Paired comparison is used to develop a preference hierarchy of tasks for farm wives in Dona Ana County, New Mexico.

"Computer Adoption and Characteristics of Computer Usage on Farms." Gregory A. Baker (Santa Clara University)
A survey of computer usage on New Mexico farms was conducted. Results indicated that adopters of computer technology tended to be well-educated operators of large farms with a favorable attitude toward change. Age, education, attitude toward technological change, and farm size did not influence the success of the system.

"Information Usage among Ohio Fruit Producers: A Socioeconomic Analysis." Eugene Jones, Marvin T. Batte, Gary D. Schnitkey (Ohio State University)
Producers of perishable and other farm commodities face considerable risk and uncertainty. Producers attempt to mitigate these factors by utilizing accurate and reliable information. However, socioeconomic factors influence the accomplishment of these objectives. This research analyzes the impact of socioeconomic factors on the "adequacy" of information usage for marketing decisions.

Lasers, Livestock, Perennials, and Investment (Daniel Lass, University of Massachusetts, presiding)

"Capital versus Management-Intensive Technology Adoption." Lydia Zepeda (University of Wisconsin)
Factors explaining capital versus a management-intensive technology adoption are examined with a multinomial logit model of technological choices on California dairies. Results show differences in adoption probabilities but not in the marginal effects of explanatory variables. Thus, the explanatory variables' level appears to determine the probability of technology adoption.

"Strategic Investments in Agriculture: The Case of Laser Leveling in Arizona." David P. Anderson (Texas A&M University) and Paul N. Wilson (University of Arizona)
Decisions concerning strategic investments create risks associated with time and switching costs. In the case of cotton growers in Arizona, the decision to adopt laser-leveled fields was positively related to farm size and negatively correlated with age and soil intake rates.

"Estimating Asymmetric Supply Response Functions: An Application of Burton's Model to the Ontario Hog Sector." Heather Meek and Larry Martin (University of Guelph)
Asymmetric supply response is hypothesized to be an important explanatory factor in an increased hog production trend in Ontario from 1975 to 1988. A nonlinear hog supply specification is estimated, and the results indicate that asymmetric supply response in hog production exists.

"Planting Decisions for Perennial Crops: A Dynamic Unobserved Components Approach." N. G. Kalaitzandonakes and J. S. Shonkwiler (University of Florida)
In perennial crop supply analysis, separate estimation of the qualitatively different new planting and replanting investment relationships is desirable. Commonly, data paucity restricts estimation to a single reduced-form equation. This study develops a dynamic unobserved components method where separate estimation of the structural equations is possible without specific data on new plantings and replantings.

"Short-Run Output Response in the Western Canadian Cattle Industry." Theodore M. Horbulyk (University of Calgary)
The results of recent empirical work are interpreted with respect to the short-run production flexibility of cow-calf producers in western Canada. The principal findings are that many of the short-run supply and factor demand responses of firms are elastic with respect to within-season price variability.

Technical Change and Productivity Growth (Michelle Marra, University of Maine, presiding)

"Endogenous Regional Agricultural Production Technologies." Chris Fawson (Utah State University) and C. Richard Shumway (Texas A&M University)
This research examines and compares estimates of technical bias for each of ten multistate farm production regions comprising the contiguous forty-eight states of the United States. The applied methodology allows for price-dependent aggregate technical choice and stochastic variation of the production technology in computing measures of technical bias.

"Factor-Augmenting Technical Change as a Stochastic Process." J. Stephen Clark, W. Hartley Furtan, and Julia S. Taylor (University of Saskatchewan)
Technical change is modeled as a general stochastic process. The pure time trend model of measuring technical change is rejected for a translog system using aggregate Canadian data. We find that technical change is more appropriately measured as a random walk with drift.

"Can Productivity Growth Sustain Real Net Incomes in Agriculture?" Gary E. Bond (International Finance Corporation) and Stanley R. Thompson (Ohio State University)
An analytical framework decomposing real farm income movements into productivity, terms of trade and other components in presented. Analysis of data from thirteen countries shows productivity growth in all but one has been insignificant.

"Technical Change and the Derived Demand for Cotton in the U.S. Textile Industry." Shangnan Shui and John Beghin (North Carolina State University)
Using time-series data we estimate a linear logit model of cost shares of fiber use in U.S. textile production, which incorporates the impact of technical change and partial adjustment on the derived demand for cotton, wool, and manmade fibers. Technical change has decreased cotton use in U.S. textile mills.

"The Political Economy of Technical Change." John W. McClelland and George Frisvold (RTD ERS USDA)
This paper discusses issues that determine the pace and direction of technical change in U.S. agriculture. Impacts of changes in environmental legislation, patent policy, R&D funding, and farm policy introduce a CGE analysis. Technology parameters in the model are restricted to 1960 levels and effects of a stagnant technology on sector prices analyzed.

Assumptions and Elasticities (Utpal Vasavada, Université Laval, presiding)

"Measurement Error Tests of Separability in State-Level Agricultural Technology." Hongil Lim and C. Richard Shumway (Texas A&M University)
Stochastic tests of separability in agricultural production technology were conducted for eleven states. The empirical findings do not rule out a reasonable amount of data aggregation, both among outputs and inputs. The nature and extent of the justified aggregation varies among states.

"Dynamic Factor Demands in U.S. and Canadian Agriculture." Susan M. Capalbo (Montana State University), Michael D. Denny (University of Toronto), and Jane Friesen (Simon Fraser University)
We develop and estimate a set of data-based dynamic factor demand models for U.S. and Canadian agriculture. Data-based models attempt to let the data describe the dynamic process underlying the observed time-series data. The results suggest little support for the equilibrium factor demand model in either country.

"How Misleading Can Allen Elasticities of Substitution Be?" Timothy G. Taylor and Gautam Gupta (University of Florida)
The Allen elasticity of substitution has recently been shown to be an incorrect measure of substitutability when there are more than two inputs. This paper presents an empirical comparison of the Morishima and Allen Elasticities based on a translog cost function estimated using data for aggregate southeastern U.S. agriculture.

"Fixed Effects and Stochastic Frontier Estimates of Firm-Level Technical Efficiency." Boris E. Bravo-Ureta, Ricardo E. Quiroga, and Laszlo Rieger (University of Connecticut)
Parameter estimates from OLS, fixed effects and stochastic production frontier models are compared using panel data for a sample of Vermont dairy farms. The results confirm that OLS production function models without firm effects lead to biased estimates. The estimates from the production frontier model are also deemed to be biased.

"Measures of Scope and Scale Economics Using a Dynamic Framework." J. Fernandez-Cornejo, C. M. Gempesaw, II, and J. G. Elterich (University of Delaware), S. E. Stefanou (Pennsylvania State University)
Measures of multiproduct economies of scale and scope developed from static dual models are extended to a dynamic cost of adjustment framework using a dual cost function. These measures are em-

pirically estimated for German dairy producers in the presence of a production quota.

Chemicals, Health, and Sustainable Production (Ted Horbulyk, University of Calgary, presiding)

"The Economics of Storage Technology." Erik Lichtenberg (University of Maryland) and David Zilberman (University of California, Berkeley)
We present a framework for analyzing decisions about storage technology (pesticides, irradiation, temperature/humidity control). Policies that reduce the effectiveness or raise the cost of spoilage reducing inputs affect both total output and the temporal distribution of consumption. Future consumption and market welfare will decline, but overall consumer (producer) income may increase if future demand is elastic (inelastic).

"Health Costs of Long-Term Pesticide Exposure in the Philippines—A Medical and Economic Analysis." Prabhu L. Pingali and Cynthia Marquez (International Rice Research Institute)
Medical examination of a sample of Philippine farmers found a significant proportion suffering chronic health effects attributable to pesticide use. Farmer health costs are positively associated with total pesticide use, the hazard category of pesticides used and unsafe handling procedures. Relatively lower labor productivity can be expected of affected farmers.

"Toward Efficient Use of Swine Manure: In a Sustainable Agricultural Production System." Vern Pierce, Jim Kliebenstein, and Mike Duffy (Iowa State University)
This study includes development of typical Iowa crop/livestock farm production systems using an economic engineering analysis. Information evaluated for these case study farms include labor constraints, manure application strategies, crop nutrient need support, and projected farm income levels. The evaluation is done in a linear programming framework.

"Dynamic Optimization of Feed Quality and Quantity in Fish Culture." Oscar Cacho and Upton Hatch (Auburn University)
A dynamic programming model is presented that determines the optimal trajectory of feeding rate and dietary protein for catfish culture. Deterministic and stochastic versions of the model are compared. The stochastic solution yielded higher optimal protein, lower optimal feeding rate, and a 4.2% increase in profit over the deterministic case.

"Economic Determinants of Chemical Residues on Agricultural Crops: Tobacco and Maleic Hydrazide." Bruce A. Babcock (Iowa State University) and William E. Foster (North Carolina State University)
Maleic hydrazide (MH) residues on North Carolina tobacco respond to economic incentives. Regression estimates indicate a 10% increase in price implies a 7% decrease in residues; a 10% increase in wages implies a 3.5% increase. A 95% assurance rate that residues are below 80 ppm requires a doubled MH price, decreasing annual producer welfare by $2.7 million.

Sources of Production Inefficiency (Carl Nelson, University of Illinois, presiding)

"Risk-Corrected Efficiency Measures." Charles B. Moss, Nicholas G. Kalaitzandonakes, and Timothy G. Taylor (University of Florida)
Farrell's seminal paper spawned economic efficiency measurement as an important topic in agricultural economics research. Similarly, risk has long been recognized as an important dimension in decision making at the firm level. However, little integration has occurred between the two sets of literature. This study suggests one approach for integration.

"Nonparametic Efficiency Measurement: Using Complementary Information from Radial and Nonradial Measures." Steven C. Deller (University of Maine) and Carl H. Nelson (University of Illinois)
We show that, when calculating measures of technical efficiency, comparison of radial and nonradial efficiency measures can provide important information that is not available from either measure alone. This information is important when the efficient reference technology contains isoquant segments that are parallel to coordinate axes.

"Share Tenancy and Allocative Inefficiency." Hyunok Lee and Agapi Somwaru (ERS USDA)
A nonparametric frontier technology was formed by the observations of eighty-two rice farms in California to model optimal input use under various share cropping contracts. The results suggest profit loss from price (allocative) inefficiency resulting from share-renting. Price inefficiency also varies with the contract rule.

"The Technical Efficiency of Corn Farms in the Corn Belt: A Methodological Note." Hisham S. El-Osta, Robert A. Pelly, and Gerald W. Whittaker (ERS USDA)
Extreme observations may generate biased parameter estimates when corrected ordinary least squares (COLS) is utilized in technical efficiency studies. While most studies employ ad hoc procedures, this study suggests the use of "minimization of absolute deviation" as an alternative to COLS.

"The Relationship between Technical Efficiency and Farm Characteristics in the Stavropol Region, USSR." Karl D. Skold (Iowa State University)
Estimates of technical efficiency in crop production are generated using the stochastic frontier approach. Individual farm-level technical efficiency estimates are generated for grain, corn, sunflower, and vegetable production. These efficiency estimates are then related to farm organization structures, labor payment methods, and direct characteristics.

Nontraditional Inputs and Efficiency (William Foster, North Carolina State University, presiding)

"Labor Contracting and a Theory of Contract Choice in California Agriculture." Ann M. Vandeman, Elisabeth Sadoulet, and Alain de Janvry (University of California, Berkeley)
We present a model of labor contract choice where seasonality, sensitivity to labor quality and work intensity, and the relative efficiency of labor contractors in recruitment and extracting work determine the choice of employment contract. We estimate the probability of contracting and wages as functions of worker and job characteristics.

"Economic Measures of the Effect of Intellectual Property Rights on Plant Breeding." William E. Foster and Richard Perrin (North Carolina State University)
The paper presents a model of economic incentives for plant breeding research and examines the effects of the Plant Variety Research Act on the pattern of breeding activity across twenty-four crops and on the pattern of breeding activity in soybeans through time.

"Computer Appliciations by Ohio Commercial Farmers." Jean J. Botomogno (Dschang University Center); Marvin T. Batte, Gary D. Schnitkey, and Eugene Jones (Ohio State University)
The evolution of microcomputer technologies has been paralleled by the evolution of software suitable for farm applications. This research identifies factors that influence the number and type of applications for which farm computers are used. Multinomial logit analyses were utilized to determine factors associated with farmers' choices of computer applications.

"Efficience technique dans le secteur laitier québécois." Nabil Amara and Robert F. J. Romain (Université Laval)
A partir d'un modèle probabiliste et paramérique d'une fonction de production frontière dans la productin laitière au Québec, deux approaches furent confrontées pour construire des indices d'efficience technique. Le niveau d'efficience s'est avéré (plus de 80%) et sa distribution assez concentrée. Une conclusion majeure est l'indépendance entre l'efficience technique et la taille de l'entreprise. De plus, des variables socio-économiques (gestion, scolarité, . . .) qui influencent l'efficacité technique ont également été identifiées.

"Decomposition Measures of Technical Efficiency for Ontario Dairy Farms." Alfons Weersink, Calum G. Turvey, and Abdullahi Godah (University of Guelph)
Technical efficiency measures are decomposed for Ontario dairy farms using nonparametric methods. Higher efficiency levels were associated with larger herd sizes. Variation in optimal scale between herd sizes, however, implies a range of farm sizes will continue to exist provided the appropriate technology for the scale of operation is chosen.

Issues Affecting Financial Intermediaries (Alan D. Barkema, Federal Reserve Bank of Kansas City, presiding)

"An Empirical Analysis of Duration Based Financial Hedging Strategies." William Thompson and David Leatham (Texas A&M University)
This paper compares a duration based hedging strategy with a combination of a duration and spread-hedging strategy that includes hedging changes in the yield curve. The duration and spread hedge reduced lender's interest rate risk associated with fixed-rate loans by 89% compared to 68% for the duration based hedges.

"An Evaluation of Alternative Hedging Strategies for Federal Farm Credit Bonds." J. C. O'Neill (Peavy Company), J. T. Akridge and William D. Dobson (Purdue University)
Strategies used by the Federal Farm Credit Bank's Funding Corporation and two alternatives for hedging anticipated liabilities were evaluated in this study. Current hedging procedures of the Funding Corporation (barbell strategy) and the price sensitivity approach performed equally well and better than a no-hedge strategy.

"Risk Behavior at Agricultural Banks." Glenn Pederson and Champak Pokharel (University of Minnesota)
A firm-level theoretical framework is developed to analyze portfolio responses of small agricultural banks in the context of bank funds constraints and imperfect loan market conditions. The estimated model suggests bankers respond to default risk and interest rate risk. Portfolio adjustments for major loan categories and securities are investigated.

"Farm Credit 'Junk' Bonds?" Douglas G. Duncan (ERS USDA) and Michael A. Singer (Texas A&M University)
The level and structure of risk premiums on Farm Credit System bonds are shown to have undergone major shifts during 1985. It is suggested that default risk was the primary cause of the shift, but more evidence is needed on the role of liquidity risk.

"Determinants of Agricultural Bank Participation in Farmer Mac: A Multinomial Logit Analysis." Clifford Rossi and Steven Koenig (ERS USDA)
Commercial banks are a primary lender group that will participate in Farmer Mac, but only 32% of agriculturally defined banks have elected to participate. A multinomial logit model estimates the factors that influenced agricultural bank participation. Results suggest that location, degree of lending specialization, loan quality, and bank size affected participation. Results suggest that initial origination volume from banks could be limited.

Farm Finance Issues (Glenn Pederson, University of Minnesota, presiding)

"Economic Analyses of Rangeland Leasing Practices and Rates." Larry Janssen, Martin Beutler, and John Cole (South Dakota State University)
Major characteristics of 444 rangeland leasing arrangement used by South Dakota ranchers were examined. Econometric modeling results indicate lease rates per acre from 1986–88 are explained by tract productivity, tract size, regional location, selected leasing practices, and by type of lease (private, state, tribal trust, or federal).

"Farm Accounting Rates of Return: Stability of Performance." Paul N. Ellinger and David A. Lins (University of Illinois)
High farm profitability is generally associated with higher business- and financial-management skills. This analysis evaluates the relative performance over time of a well-defined group of farms. Characteristics of farms that are superior producers along with farms that exhibit large and small amounts of rank variation are observed.

"Systematic and Unsystematic Risk Costs for Southeastern Kansas Farm Enterprises." Koffi N. Amegbeto and Allen Featherstone (Kansas State University)
Six measures of farm returns are used to estimate the most "appropriate" market index for southeast Kansas farms. Systematic and unsystematic risks and risk costs were estimated for farm planning. Results suggest that regional indices are more appropriate for use as the market index than state indices.

"An Application of the Single Index Model to Regional and Farm-Level Risk Analysis." Calum G. Turvey (University of Guelph)
This paper uses equally and proportionally weighted reference portfolios for determining regional and farm-level risk with the single index model. Using Ontario county-level data consideration in analyzing regional and farm-level systematic risks are presented. It is concluded that the SIM can be a useful method for managing risks in agriculture.

"Farm Consumption and Liquidity Constraints." Michael R. Langemeier (Kansas State University) and George F. Patrick (Purdue University)
This study develops a model to determine whether liquidity constraints prevent farm families from behaving according to the life cycle–permanent income hypothesis. Results, using a sample of Illinois farms, indicate that the consumption levels of an insignificant proportion of farm families are liquidity constrained. These results support the life cycle–permanent income hypothesis.

Taxes and Financial Contracts (Calum G. Turvey, University of Guelph, presiding)

"Do Farmers Pay Federal Income Tax?" Ron Durst and Clifford Rossi (ERS USDA)
This paper examines the proposition that the federal income tax provides a net subsidy to the farm sector. The net effect on federal income tax revenues from exempting farm income and disallowing farm losses for various sizes and types of farms is determined. The analysis finds that the income tax acutally results in a net surplus to the U.S. Treasury.

"Economic Depreciation and Tax Policy: The Case of Combine Harvesters." John Goroski, Vincent H. Smith, Joseph A. Atwood, and Myles J. Watts (Montana State University)
An econometric model of depreciation is constructed for combine harvesters to test the hypothesis that the rate of depreciation is constant over the life of the asset. This hypothesis is rejected. Depreciation is shown also to depend on tax policy and demand shift variables such as gross farm income.

"Agricultural Resource Adjustment and Capital Gains Taxation." Michael LeBlanc and James Hrubovcak (RTD ERS USDA), Ron Durst (ARED ERS USDA), and Roy Boyd (Ohio State University)
This paper examines the effects and implications on agriculture, forestry, and resource conservation of the president's proposal to reduce the tax on capital gains. A general equilibrium approach is adopted to capture the competition for resources.

"Debt Service Reserve Fund (DSRF) as a Response to Repayment Risk." Madhab Raj Khoju (University of Illinois)
Debt service reserve fund (DSRF) plan as a response to repayment risk seems appealing to both the parties in a loan contract. However, its size and other design specifications should also be acceptable to both parties. A theoretical model for determining lender and borrower optimal size of DSRF is developed and its application potential demonstrated.

"Limited Liability, Moral Hazard, and the Theory of the Farm Firm." Robert Innes (University of California, Davis)
This paper analyzes the optimal input, output and contractual choices of a risk-neutral producer who borrows from "outside" investors, makes an unobservable effort choice, and is subject to limited liability on his investment contract. The optimal financial contract is found to resemble a combination of a standard debt instrument and a commodity bond.

International Dimensions of Agricultural Finance (Barry K. Goodwin, Kansas State University, presiding)

"On the Relation between Adjusted Basis and Hedge Results." Francesco S. Braga (University of Guelph)
The results of a hedge placed on futures priced in a foreign currency are not uniquely related to adjusted basis changes unless the proper currency hedge is also in place. Empirical evidence for the corn and soybean markets in Chatham, Ontario, is provided for the period from January 1981 to April 1989.

"Group Credit in Costa Rica: An Analysis of Information Transfer." Mark D. Wenner (ERS USDA)
Group lending with joint liability is a promising innovation in financial intermediation involving smallholders. Signaling theory is used to examine the effect of improved information regarding borrower creditworthiness on loan repayment rates. Costa Rican data is used for analysis.

"Experimental Measurement of Discount Rates in Rural India." John L. Pender (Stanford University)
Discount rates of individuals in south India were measured using experimental games with significant rewards. Increasing the time frame or magnitude of rewards reduced discount rates consistent with previous studies using hypothetical questions. The discounted utility model is inconsistent with the results of the games.

"Farm Household Access to Credit Markets Under the Household Responsibility System in China." Loraine A. West (Stanford University)
Rural credit markets in China are examined and a logit model is used to identify farm households rationed out of the formal credit sector. Results indicate the primary rationing criterion is loan use and this is largely caused by the institutional structure of credit cooperatives and homogeneity of farmers.

"Credit Rationing in Rural Financial Markets: A Portugese Study Case." Nelson A. Aguilera and Douglas H. Graham (Ohio State University)
This paper demonstrates that, to analyze credit discrimination, one should have a well-defined demand and supply model. This model should be estimated using data on both loans granted and loans rejected. The criteria by which credit applications were rejected or accepted should also be explicitly incorporated into the analysis.

***Ex Post* Analysis of the 1980s Financial Crisis (Bruce L. Ahrendsen, University of Arkansas, presiding)**

"Community Development and Commercial Bank Performance: A Mutually Dependent Relationship." Shaun Beauclair and Cole Gustafson (North Dakota State University)
To test the circular relationship between bank lending practices and community development in North Dakota countries, a two-stage simultaneous regression using pooled cross-sectional, time-saving data from 1972–86 was constructed. Increased credit at retail, wholesale, and farm levels heightens economic activity and leads to greater loan demand and bank profitability.

"Analysis of Restructured Loan Nonperformance." Glenn Pederson and Ananth Rao (University of Minnesota)
Post-restructure performance of Federal Land Bank loans is analyzed using logit regression. Financial variables (debt structure index, gross cash farm income) are found to be inversely related to the odds that a restructured loan would not perform. Restructure variables (interest rate, collateral ratio) are positively related to loan nonperformance.

"Nature and Success of Voluntary Financial Workouts: A Case Assessment of Wyoming Bankers and Borrowers." Alan Schroeder and Larry J. Held (University of Wyoming)
The voluntary efforts of agricultural lenders to develop workout plans with troubled borrowers are examined. Survey results of Wyoming bankers suggest voluntary workouts are used both extensively and successfully—being initiated in over two of three de-

fault cases with successful results in nearly 70% of their workout cases.

"Examination of Chapter Twelve Farm Reorganization Bankruptcy Filings and Approved Reorganization Plans." Burton Pflueger and Larry Janssen (South Dakota State University)
Major financial characteristics of Chapter Twelve farm debtors and their creditors are examined in South Dakota, a state where reorganization bankruptcy is widely used. Debt reduction and other characteristics of 101 confirmed reorganization plans are presented. FmHA and commercial banks had the least amount of debt recovery.

"Estimates of Bankruptcy under Chapter Twelve." Robert N. Collender (North Carolina State University/ERS) and Theodore A. Feitshans (North Carolina State University)
Using White's model of indirect bankruptcy costs we find that total bankruptcy costs under Chapter Twelve may be as high as 106% of asset value at time of filing for 106 farms in North Carolina. This compares to White's estimates of 60% for a cross-section of firms filing under Chapter Eleven.

Theoretical Issues in Risk Analysis (Michael E. Wetzstein, University of Georgia, presiding)

"Risk versus Uncertainty and the Value of Waiting to Invest." Richard S. Gray (University of California-Berkeley)
If information arrives over time, there is some value in waiting to make an investment involving a sunk cost. Recent work, which specifies the nature of the stochastic process for prices, has shown the standard investment rule—to accept projects whenever net present value is postive—is generally quite wrong.

"A Simple Duality Model of Production Incorporating Risk Aversion and Price Uncertainty." Barry T. Coyle (University of Manitoba)
Proceeding within the framework of a linear mean-variance utility function, this paper develops a duality model of production that incorporates risk aversion and price uncertainty. In contrast to risk models based on an expected utility function, this model provides a practical alternative to standard duality models for econometric research.

"Quadratic Risk Programming—Expected Utility Maximization Consistency and Elliptical Symmetry." Carl H. Nelson (University of Illinois)
Results of Meyer are extended to multivariate portfolio choice problems. If a set of random variables is elliptically symmetric and is linearly combined, then expected utility is solely a function of the mean and variance of returns. Risk-averse decision makers will choose from the mean–standard deviation efficiency frontier.

"Relaxing the Expected Utility Hypothesis and Entry/Exit Decisions of the Risk-Averse Firm." Israel Finkelshtain and Julie Ann Hewitt (University of California)
A risk aversion theory is formulated directly from a preference relation, rather than with a utility function representation. An example concerning insurance demand provides intuitive support. This theory is applied to analyze firms' entry/exit decisions, the long-run equilibrium of an industry and comparisons between firms with different risk attitudes.

"Comparative Statics for Rank-Dependent Expected Utility Theory." John Quiggin (University of Maryland)
A number of generalizations of the expected utility (EU) model have been proposed. Rank-dependent expected utility (RDEU) theory is a generalization of EU theory based on the concept of probability weighting. A major class of comparative static results can be extended to the RDEU model but not to the case of general smooth preferences.

Risk Management in Marketing and Policy (Michael Bowker, Nova Scotia Agriculture College, presiding)

"Risk Analysis in the Ontario White Bean Sector." Mike von Massow, Alfons Weersink, Scott Rozelle, and Calum G. Turvey (University of Guelph)
Utilizing variance decomposition procedures, changes in the average and variance of Ontario white bean production are found to be largely the result of changes in acreage. Risk elements were incorporated into an acreage response model. Results indicate acreage is affected more by the expected values of prices and yields rather than its associated risk parameters.

"L'impact des programmes et assurances agricoles sur la production de maïs au Québec." Evelyne Martel and Robert Romain (Université Laval)
L'impact de la réduction de la variabilité des rendements et des prix sur la production de maïs au Québec a été estimé. Vu la caractéristique du programme d'assurance-stabilisation des revenus qui garantie le coût de production d'une ferme-type, une augmentation de la variabilité des prix fera augmenter les ensemencements.

"Risk Management in the Marketing of Sweet Potatoes: An Application of Target MOTAD." Larry L. Bauer (Clemson University)
The yield of sweet potatoes increases after the crop is initially ready for harvest and can be sold at har-

vest or cured and stored for later sale. Target MOTAD is used to analyze the decisions of when to harvest and when to market.

"Production, Hedging, and Speculative Decisions with Options and Futures Markets." Harvey Lapan and Giancarlo Moschini (Iowa State University), Steven Hanson (Michigan State University)
This paper analyzes production and hedging with both futures and options, given price and basis risk using the expected utility model. When markets are perceived unbiased, optimal hedging involves using only futures (options are redundant). Options are used together with futures as speculative tools when markets are perceived biased.

"The Calibration of Expected Soybean Price Distributions: An Option-Based Approach." Bruce J. Sherrick (University of Illinois), D. Lynn Forster and Scott H. Irwin (Ohio State University)
No-arbitrage option pricing models are used to recover complete probabilistic descriptions of expected soybean futures prices. The usefulness of the approach is examined via calibration tests. Results indicate that the estimated distributions are fairly reliable and that a three-parameter Singh-Maddala distribution is useful in characterizing expected prices.

Risk Analysis of Crop Insurance, Diversification, and Pest Management (Mark Cochran, University of Arkansas, presiding)

"The Impact of Risk on Pest Management Strategies." Uri Regev (Ben-Gurion University)
The paper analyzes the effects of pest-related uncertainties on pest control tactics and strategies. In general, increasing uncertainty of various pest aspects will not necessarily lead to increased pest control application. Pesticides, are often conceived by farmers as risk reducing but are risk increasing in the long run.

"Returns to Limited Crop Diversification." Steven C. Blank (University of California, Davis)
A new single-index model application enabling users to more easily assess risk/return tradeoffs between crop portfolios is suggested. A decision criterion is presented, based on a new crop portfolio performance measure. The procedure helps reduce data sensitivity problems often faced when using quadratic programming or standard SIM techniques.

"A Comparison of Subjective and Historical Yield Distributions with Implications for Multiple Peril Crop Insurance." Jean C. Buzby (University of Kentucky), Phil L. Kenkel (Oklahoma State University), Jerry R. Skees (University of Kentucky), James W. Pease (Virginia Polytechnic Institute and State University), and Fred J. Benson (University of Kentucky)
This study examines the relationship between subjective yield distributions elicited from Kentucky farmers in 1987 and 1989 and their historical yield distributions. The results indicate a close correspondence between the first two moments of the distributions. The evidence suggests that farmers underestimate their downside risk.

"A Comparison of Crop Yield Coverage Plans for Multiple Peril Crop Insurance." Gerald D. Toland, Jr. (Southwest State University), Brian H. Schmiesing (South Dakota State University), and J. Roy Black (Michigan State University)
Producers' purchase decisions for multiple peril crop insurance (MPCI) were analyzed under the AREA and Actual Production History (APH) Coverage Plans. Global certainty equivalents were determined to predict MPCI purchases in a simulation using subjective crop yield probability distributions. The frequency of predicted MPCI purchases increased under the APH plan.

"Area-Yield Crop Insurance Reconsidered." Mario J. Miranda (Ohio State University)
Crop insurance that bases both premiums and indemnities on the aggregate yield of a surrounding area provides more effective yield-loss coverage than individually tailored insurance and avoids most of the adverse selection and moral hazard problems that have historically undermined the actuarial performance of the Federal Crop Insurance Program.

Incorporating Risk into Economic Models (Harry Hall, University of Kentucky, presiding)

"Economies of Scale and Output Flexibility in Northeastern U.S. Dairy." Adesoji O. Adelaja and Madalene C. Bruun (Rutgers University)
In northeastern U.S. dairy, capital intensity, risk, and specialization are shown to increase with size, while output flexibility or responsiveness is shown to decrease with size. The greater flexibility of smaller farms is shown to make them as viable as larger farms despite economies of scale.

"Measuring Scale and Technical Change from Observable Data Under Uncertainty." Paul R. Flacco (East Carolina University) and Douglas M. Larson (University of California, Davis)
Returns to scale and technological change can be measured without econometric estimation for industries with output price uncertainty using panel data. Since expected utility maximization implies cost minimization, with panel data it is possible to approximate marginal cost using observed prices and

quantities, from which scale and productivity measures follow.

"A Regional Analysis of U.S. Corn Yield Variability." John W. Wade, Michael S. Kaylen, and Deon Frank (University of Missouri)
Regional corn yield models which incorporate stochastic trends, prices, and weather variables are developed. Empirical 1989 U.S. corn yield distributions are generated with weather and estimated residuals as the sources of randomness. Hypothesis tests suggest yield variability has been increasing, with weather changes being a major source of this increase.

"A Simple, Efficient, and Theoretically Correct Approach to Simulation Analysis." W. G. Boggess, O. A. Ramirez, and C. B. Moss (University of Florida)
This study uses the multivariate hyperbolic sine probability density function as a basis to develop a simple, efficient, and theoretically correct approach for generating correlated, non-normal random variables.

"Modeling Cyclical Cattle Prices in a Monte Carlo Setting." Larry W. VanTassell (University of Tennessee), J. Richard Conner and James R. Richardson (Texas A&M University)
A methodology for simulating harmonic regressions is presented that allows for the stochastic simulation of the harmonic regressions when various orders of autocorrelation are present. Statistical properties of the historical correlations are respectably maintained in an empirical example using ten livestock classes which exhibit first- and twelfth-order autocorrelation.

Issues in Interregional and International Marketing (Ellen Goddard, University of Guelph, presiding)

"Spatial Equilibrium in Fluid Milk Markets." Howard McDowell and Ann Fleming (ERS USDA)
Fluid milk markets are compared in an interregional trade framework as currently regulated with the single price-basing region, regulated multiple price-basing regions, and under competitive market conditions. Simulated prices and dairy surpluses are highest under current regulations, followed successively by multiple-region price basing, and competitive conditions.

"Repeat Purchase and Switching Probabilities in the International Wheat Trade." William W. Wilson and Kin N. Lau (North Dakota State University)
Models of purchasing behavior are of particular importance in understanding intercountry competition in specific import markets. In this paper, a model was developed which incorporates the impacts of both stationary and nonstationary phenomena on purchasing behavior. The results are illustrated for two important wheat importing countries which have distinctly different characteristics, Japan and the USSR.

"Application of Intervention Analysis to a Trade Restriction: The Case of Canadian Potash." Harry L. Vroomen (ERS USDA)
Intervention analysis is used to analyze the impacts of the 1987 U.S. antidumping case against Canadian potash producers. The case resulted in significantly higher potash prices, leading to increased U.S. farm costs of a half billion dollars through June 1989 and increased revenues for both U.S. and Canadian potash producers.

"The Impact of Liberalizing Trade on the World Rice Market." Gail L. Cramer, Eric J. Wailes, and Stanley S. Philips (University of Arkansas)
A spatial equilibrium model of world rice trade was utilized to estimate the impact of world trade liberalization. Rice trade was separated into high-quality indica, low-quality indica, and japonica. Models of free trade, constrained free trade, and industrialized market economy liberalization were developed, assessed, and compared.

"Attitudes Toward Beef in Hokkaido, Japan." P. L. Klein, K. K. Klein, and S. Yoshida (University of Lethbridge, Alberta, Canada)
Consumers in Hokkaido, Japan, were surveyed about their attitudes toward consumption of beef. It was found that Hokkaido residents eat very little beef, particularly imported beef. Consumption seems to be sensitive to income and price changes; this has important implications since Japan has recently reduced import restrictions on beef.

Producer Response to Marketing Issues (T. Randall Fortenbery, North Carolina State University, presiding)

"Short-Run Aggregate Catfish Producer Supply Response to Production and Price Risk." William Branch and Daniel S. Tilley (Oklahoma State University)
Short-run aggregate supply response to production and price risk is estimated using ordinary least squares. A statistically significant, positive response to input and output price risk is indicated. Results suggest processors and feed manufacturers may want to consider alternative pricing strategies designed to reduce risk in the system.

"Risk Management for Livestock Producers: Hedging and Contract Production." John D.

Lawrence (University of Minnesota) and Michael S. Kaylen (University of Missouri)
A chance-constrained stochastic dynamic programming model is developed to analyze risk management for hog finishing operations. Optimal placement, ownership, and hedging decisions are found under production and price uncertainty and are compared via simulation.

"Area Responsiveness of Canola on the Canadian Prairies." T. Richards and K. K. Klein (University of Lethbridge, Alberta, Canada)
The objective of this study is to determine if the elasticity of area planted to canola has changed now that the crop has attained a more "mature" status. The area in western Canada planted to canola was modeled using several specifications. The results suggest the crop has a much lower output elasticity than what was previously estimated, where previous estimates were based on data recorded before 1978.

"On Nonlinear Dynamics: The Case of the Pork Cycle." Matthew T. Holt and Jean-Paul Chavas (University of Wisconsin)
New methods for analyzing nonlinear dynamic processes are used to evaluate the hog-corn price ratio. The results present evidence of nonlinear dynamics in the pork cycle. Moreover, while GARCH processes account for some non-linearities, the pork cycle is apparently characterized by more complex dynamic forms.

"Nonparametric Analysis of Cost Minimization and Changes in Cigarette Characteristics." Ruey-er Chang (North Carolina State University/AT&T) and Daniel A. Sumner (North Carolina State University/USDA)
Nonparametric analysis indicates the presence of violations of cost minimization in the combination of different tobacco types in cigarette manufacturing. However, regression of the degree of violation of cost minimization on change in product characteristics indicates the significant impact of exogenous shifts in cigarette attributes on cost shifts.

Issues in Advertising and Consumer Demand (Gary W. Williams, Texas A&M University, presiding)

"Lag Structures in Commodity Advertising Research." Jonq-Ying Lee and Mark G. Brown (Florida Department of Citrus)
This paper examines basic assumptions about the lag structure of advertising. Evidence suggests for frequently consumed commodities, the lag structure is probably a monotonic decreasing function. Confusion may exist over advertising variables used and the shape of lag structure. Cumulative structures need to be differentiated from decay structures.

"Product Labeling, Advertising, and Demand for Grapefruit Juice and Grapefruit-Juice Cocktail." Mark G. Brown, Jonq-Ying Lee, and Robert M. Behr (Florida Department of Citrus)
Demand relationships for two closely related products—grapefruit juice and grapefruit-juice cocktail—were estimated to analyze the contention that consumer confusion exists between the two products. Results suggest confusion may exist, with grapefruit-juice advertising not only increasing the demand for grapefruit juice but also for grapefruit-juice cocktail.

"Factors Influencing Bids for Vacuum-Packaged Retail Beef: An Experimental Economics Approach." George W. Borden, Dale J. Menkhaus, Glen D. Whipple, and Ray A. Field (University of Wyoming); Elizabeth Hoffman (University of Arizona)
Tobit analysis was used to identify factors influencing the value consumers place on beef steaks in a vacuum skin package relative to steaks in an overwrapped styrofoam tray. Experimental economics was used to obtain value information. Results suggest that information regarding the vacuum skin package enhances the value of beef.

"Consumer's Preferences Regarding Steaks: A Market-Oriented Approach." Roger Paguaga Barreto, Francesco Braga, Larry Martin, Victor Roth, and Ron Usborne (University of Guelph)
The southwestern Ontario beef steak market can be divided into five segments on the basis of consumer's product characteristics preferences. The beef industry should consider changing its current commodity focus to a more market responsive approach in order to satisfy and exploit the opportunities offered by these market segments.

"Factors Influencing Consumer Rankings of Alternative Retail Beef Packaging." Pierre M. L. Pelzer, Dale J. Menkhaus, Glen D. Whipple, and Ray A. Field (University of Wyoming); Elizabeth Hoffman (University of Arizona)
Ordered probit models were used to identify factors which influence consumer rankings of vacuum skin packaged steaks and roasts. Information pertaining to the color of the beef in, and the benefits of, the vacuum skin package was among the most important factors for enhancing the preference for this package type.

Information in Price Determination (Raymond Leuthold, University of Illinois, presiding)

"Price Transmission Across Marketing Levels in a Hedonic Framework." Douglas D. Parker and David Zilberman (University of California, Berkeley)

This paper analyzes the behavior of prices for a perishable product as functions of time and product quality characteristics. A conceptual model analyzing the behavior of the marketing margin is developed. The results identify potential gains from improving quality and developing price signals which compensate for characteristics other than weight.

"Effect of Contract Disclosure on Price: Railroad Grain Contracting in the Plains." Stephen Fuller, Fred Ruppel, and David Bessler (Texas A&M University)

Staggers Rail Act of 1980 granted railroads freedom to establish rates and enter into confidential contracts with grain shippers. Recent legislation (1986) required contract terms to be disclosed. This study shows rail rates in the plains region commenced an upward trend after implementation of the disclosure policy. Results suggest disclosure increased reliance on posted tariffs which subsequently facilitated rate coordination among the oligopolistic railroad industry.

"L'impact de la vente par encan électonique centralisé: quelques résultats préliminaires au Québec." Zhigang Chen, Carol Gilbert, and Rebecca Lent (University of Laval)

A series of preliminary tests as well as an analysis by vector autoregression (VAR) confirm certain hypotheses concerning the impact of the electronic auction market on the primary hog market in Quebec. Hog prices have become more sensitive to changes in corn and pork prices, indicating an improvement in information conditions.

"Are Pre-Release Estimates of USDA Hogs and Pigs Reports Rational?" Phil L. Colling and Scott H. Irwin (Ohio State University)

For expectations to be rational, they must incorporate all available, relevant information. This study investigates the rationality of pre-release estimates of USDA *Hogs and Pigs* reports. The estimates are rational in that they are unbiased predictors, their forecast errors are not autocorrelated, and they incorporate all available, relevant information.

"The Rationality and Value of USDA Crop Forecasts." Fen-Chin Yu and Peter Orazem (Iowa State University)

Forecasts of barley, corn, oats, soybeans, and spring wheat planted acreage and harvest size are investigated. Several forecasts are found to be inefficient and/or biased. Nevertheless, these forecasts can substantially improve market supply information. Early forecasts are much more valuable than later forecasts.

Current Issues in Price Determination (Ed Estes, North Carolina State University, presiding)

"Factors Affecting Spring Season Fresh Peach Prices." Charles Hall and Stephen Fuller (Texas A&M University)

This research measures factors affecting weekly spring peach price. Results show own-shipments, peach size, origin, and competing fresh fruits have an important influence. Potential producers must give attention to early varieties, whereas later-maturing varieties may be profitable as a result of the observed premium associated with larger-sized fruit.

"Testing for Supply Asymmetry in the Market for Organic Lettuce." L. Lohr (Michigan State University) and Timothy Park (University of Nebraska)

Organic grower certification may require farmers to adopt a bundle of new technologies or inputs. Divestment and subsequent reinvestment in the certification process incur costs which may be a source of irreversibility in the supply function. This paper tests for supply asymmetry in the market for organic lettuce in California.

"Market Integration, Efficiency of Arbitrage, and Imperfect Competition: Methodology and Application to U.S. Celery." Richard J. Sexton, Catherine L. Kling, and Hoy F. Carman (University of California, Davis)

This paper develops and applies a methodology to test for efficiency in interregional commodity arbitrage. The methodology is empirically manifest as a switching regression model with three regimes: efficient arbitrage, relative shortage, and relative glut. Results from application of the model to U.S. celery marketing indicate significant departures from efficient arbitrage for both California and Florida celery.

"Price Determination and Acreage Adjustment Before and After the Implementation of a Marketing Order." Richard L. Kilmer and Timothy G. Taylor (University of Florida)

Price determination and planted acreage adjustments are evaluated before and after the installment of a marketing order in the Florida celery industry. The industry deviated from marginal cost pricing. However, current acreage planted was influenced by different factors before the marketing order than after.

"The Effect of Non-Phenotypic Data in Price Determination of Thoroughbred Yearlings." Malcolm Commer, Jr. (University of Maryland)

The equine sector of American agriculture is a virtually unresearched area. This paper investigates price determination factors in the thoroughbred market. Through regression analysis, four continuous independent variables and six sets of indicator independent variables were found to be statistically significant at the .05 level or greater.

Use and Efficiency of Futures Markets (Elunid Jones, Virginia Polytechnic Institute and State University, presiding)

"The Price Adjustment Process and Efficiency of Grain Futures Markets Implied by Return Series of Various Time Intervals." Shi-Miin Liu and Sarahelen Thompson (University of Illinois)
This study investigates the price adjustment process and efficiency of corn and oats futures markets using data from the 1986 contracts traded on the CBOT. Amihud-Mendelson's (1987) model, Box-Jenkins' (1970) techniques, and Black's (1986) criteria are employed. The competitive performance of speculators in grain futures markets is also examined.

"Nonstationarity of Soybean Futures Price Distributions: Option-Based Evidence." Bruce J. Sherrick (University of Illinois), Scott H. Irwin and D. Lynn Forster (Ohio State University)
No-arbitrage option pricing models are used to estimate *ex ante* soybean futures price distributions. Volatility measures of these distributions are modeled in an endogenous-switchpoint regression as functions of price level and time-to-maturity. Results indicate volatility measures are not stationary and exhibit regime-dependent influences of time-to-maturity and price level.

"How Efficient Is the Rough Rice Futures Market?" Linwood A. Hoffman (CED ERS USDA, Crops Branch)
Efficiency of the rough rice futures market is analyzed relative to the Arkansas cash market. Market activity is examined and various efficiency tests are performed. Inefficiencies were found in beginning or low volume contracts, but some market efficiency criteria improved with time and greater contract volume.

"Factors Influencing Producer Use of Futures and Options in Commodity Marketing." Larry D. Makus, Biing-Hwan Lin, John Carlson, and Rose Krebill-Prather (University of Idaho)
A probit model is used to quantify factors influencing the probability that producers used futures or options for commodity marketing. Results suggest previous use of forward contracts, location, size, having a college degree, and membership in a marketing club have the greatest impact on the probability of using futures and options.

"Hedging Effectiveness of the Winnipeg Oats Futures Market." Gary Warkentine, Milton S. Boyd, and Merle D. Faminow (University of Manitoba)
The Winnipeg feed oats futures contract was found to be an effective hedge for Canadian feed oats, as well as for food grade oats previously handled by the Canadian Wheat Board. The Winnipeg market was also found to be a more effective hedge for Canadian oats than the Chicago market.

Information and Technology Effects on Consumer Demand (Hal Harris, Clemson University, presiding)

"Milk Component Pricing via a Retail-Level Hedonic Analysis." John E. Lenz (Cornell University) and Ron C. Mittelhammer (Washington State University)
Household food consumption survey data was used in a hedonic retail-level analysis of milk component values. Protein, fat, and calcium components of raw milk were perceived by consumers to have significant value with the protein component having 28% more value than fat, on average, per point.

"Analysis of a Conjoint Study of Aquaculturally Produced Hybrid Striped Bass." Catherine Halbrendt, John D. Pesek, and J. Richard Bacon (University of Delaware)
Conjoint analysis was used to examine buyer preferences toward aquaculturally produced hybrid striped bass. The repeated measures approach was used to correct for correlation concerns associated with the aggregate approach. Results showed that buyers prefer a two- to three-pound fish that has been filleted, is available year round, and is competitively priced.

"Biotechnology and the Consumer: The Case of Bovine Somatotropin." Anya M. McGuirk, Warren P. Preston, and Gerald M. Jones (Virginia Polytechnic Institute and State University)
A mailed questionnaire is used to assess consumer concerns and potential consumption response attributable to the introduction of bovine somatotropin (BST). Responses from 605 households in Virginia are described and analyzed. Potential impacts on consumer demand for fluid milk are assessed.

"A Cross-Sectional Evaluation of Generic Advertising: The Case of Catfish." Henry Kinnucan and Meena Venkateswaran (Auburn University)
A conceptual framework for evaluating advertising effects using cross-section data is developed and applied to catfish. The eight-equation, partially recursive econometric model linking advertising awareness to beliefs, attitudes, and purchase frequency indicates generic advertising had a significant effect both on attitude and consumption of catfish.

"*Ex Ante* Evaluation of the Economic Impact of Agricultural Biotechnology in the Multiproduct U.K. Pigmeat Market." Catharine Lemieux (Indiana State University), C. Martin Palmer (U.K.

Meat and Livestock Commission), and Michael Wohlgenant (North Carolina State University)
Introduction and adoption of the growth stimulator, Porcine Somatotropin (PST), will have a significant impact on the U.K. pigmeat industry. Results indicate that, for a five-year adjustment period, producers' surplus will increase between 44 million and 101.3 million pounds; consumers' surplus will increase between 29.6 million and 65.9 million pounds.

Empirical Demand Models (James Seale, University of Florida, presiding)

"Aggregate U.S. Demand for Cheese and Animal Proteins: Analysis of Time-Series Data with Demographic Factors." Federico Perali, Thomas L. Cox, and Brian Gould (University of Wisconsin)
The Lewbel modifying function technique is applied to a demand system containing the translog indirect utility and almost ideal demand system as special cases. Scaling and translating versions of these demographically modified systems are then estimated, tested for, and compared using annual, per capita disappearance data.

"The Demand for Wine in Ontario." Lorrie MacKinnon and Bruno Larue (University of Guelph)
Two demand systems are estimated to capture the relationships between imported and domestic wines of different colors and between wines from different countries. Policy simulations were conducted to evaluate different schemes that Ontario could use in order to comply with a recent GATT ruling.

"Advertising, Information, and Product Quality: The Case of Butter." Hui-Shung Chang and Henry Kinnucan (Auburn University)
The hypothesis that health concerns affect consumers' quality perceptions about butter was tested using a cholesterol information index. The empirical results show that concerns about cholesterol decreases and DBC advertising increases the demand for butter; the negative effect is larger, in absolute sense, than the positive effect of advertising.

"Demand Trends for Beef Cuts—By Quality, Convenience, and Season." Donald E. Farris and David W. Holloway (Texas A&M University)
Total demand for beef has declined during the 1980s, but demand for the higher-valued cuts have increased relative to the average. Price ratios of retail and wholesale cuts to the carcass composite price were used to develop trends in demand for individual cuts. Increased demand for higher quality is clear; demand for convenience (steak or ground beef versus roasts) was indicated. Seasonality of demand varies among cuts.

"Simultaneity and Structural Change in Fed Beef Demand." James Eales and Inshik Lee (University of Illinois)
Simulations illustrate potential dangers of looking for structural change in demand when the true culprit is a supply shock. Applications to fed beef suggests, if demand is static, parameter shifts are significant and quantities and prices are endogenous, while, if dynamic, no significant shifts exist and prices are predetermined.

Measurement Issues in Demand Analysis (Barry Coyle, McDonald College, presiding)

"Effects of Measurement Error in Disappearance Data on Estimated Demand Elasticities for Meats." Gary W. Brester (Kansas State & North Carolina State University) and Michael K. Wohlgenant (North Carolina State University)
The traditional approach of using USDA disappearance data as a proxy for per capita consumption in estimating retail demand elasticities for meats results in biased elasticity estimates. A new procedure for obtaining unbiased estimates is developed that does not impose the assumption of fixed proportions technology in the processing sector.

"Demographic and Income Distributional Factors and Aggregation in Demand Analysis." Deborah Peterson and Timothy D. Mount (Cornell University)
Demographic and income distributional factors are incorporated into household demand systems, and theoretically consistent aggregate demand equations are derived. Food consumption data from 1980 and 1986 are used to evaluate how changes in average income, skewness of income, tax schedules, and demographic characteristics affect consumption of eight food commodities.

"A Note on Testing Separability in Nonparametric Demand Analysis." Thomas L. Cox and Jean-Paul Chavas (University of Wisconsin)
This paper seeks to clarify the empirical options for testing separability in nonparametric demand analysis. It is noted that the Afriat-Varian characterization of weak separability can be obtained only under the restrictive assumption of a concave utility function. An alternative nonparametric separability test is discussed under weaker assumptions.

"Effect of Length of Time on Measured Demand Elasticities: The Problem Revisited." Oral Capps, Jr., and Rodolfo M. Nayga, Jr. (Texas A&M University)
This study centers attention on the effect of varying lengths of time (weekly, biweekly, monthly observations) on measured demand elasticities for disag-

gregate fresh beef products. Parameter estimates and elasticities based on monthly data differ from those based on biweekly or weekly data. Generally, inventory adjustment dominates with the latter time intervals. On the other hand, for four of the six disaggregate fresh beef products analyzed, habit formation is the dominating effect with monthly data.

"Construction of True Cost of Food Indexes from Estimated Engel Curves." William Noel Blisard and James R. Blaylock (ERS USDA)
This paper applies a technique to derive true cost-of-living indexes from the estimation of a simple system of Piglog Engel curves. This technique allows a maximum amount of commodity disaggregation, and the indexes show the impact of inflation on households with different expenditure levels and demographic characteristics.

Demand Methodology (Jean-Paul Chavas, University of Wisconsin, presiding)

"Modeling Consumer Expenditures Under Rationing in People's Republic of China." Wen S. Chern and Zhi Wang (Ohio State University)
An almost ideal demand system incorporating rationing is estimated for eight consumer expenditure groups using data of 1981–87. The study compares different specifications of rationing scheme and estimation methods. The results show that the rationing in housing, grains, and fuels created excess demand for nonstaple food and consumer durables in China.

"The Slutsky Matrix, Homogeneity, and Invariance in Intertemporal Consumer Theory." Michael R. Caputo (University of California, Davis)
An *m*-member intertemporal household production model with labor supply and durable and nondurable goods is studied. The dynamic law of demand applies to cumulative discounted demand functions, rather than their instantaneous counterparts. Hence observations of upward sloping Hicksian demand functions, which refute static theory, are consistent with dynamic theory.

"Preference Change Bias in Meat Demand: An Indirectly Separable, Semiparametric Model." Giancarlo Moschini (Iowa State University)
The hypothesis that preference changes may partly explain U.S. meat consumption is tested with an indirectly separable model in semiparametric form using the kernel estimator. The results support the notion that changes in consumer preferences may explain an increased consumption of white meat and a decreased consumption of red meat.

"Symmetry and Scale Effects in a Logistic Demand System." Tim Considine (Pennsylvania State University)
This paper presents a method to impose symmetry on the linear logit model of cost shares. The underlying cost function is approximated by using the share predictions as numerical approximations of the price integrals. The concavity conditions are relatively stable functions of the cost shares.

"Incorporating Demographic Information in Demand Analysis." Basile Goungetas, Helen H. Jensen, and Stanley R. Johnson (Iowa State University)
This paper develops a method for incorporating commodity-specific demographic information into the linear approximate almost ideal demand system (LA/AIDS). As it turns out, the resulting demand system is a LA/AIDS model with the demographic variables specified as intercept shifters. The model was estimated using household expenditure data from Indonesia.

Estimates of Conjectural Variations and Implications for Analyzing Industry Conduct and Performance (Warren P. Preston, Virginia Polytechnic Institute and State University, presiding)

"Marketing Margins, Market Power, and Price Uncertainty." John R. Schroeter (Iowa State University) and Azzeddine M. Azzam (University of Nebraska)
We examine marketing margins in the case in which food-processing firms exercise product and input market power and face output price uncertainty. An empirical application reveals that farm/wholesale pork margins contain a significant oligopoly price distortion and are positively related to the level of price risk.

"Implications of Increased Regional Concentration and Oligopsonistic Coordination in the Beef-Packing Industry." Azzeddine M. Azzam (University of Nebraska) and John R. Schroeter (Iowa State University)
Previous empirical studies of packer market power in cattle procurement either follow the ad hoc "structural approach" of the Bain tradition or conduct the analysis at the national level. This paper combines an explicit behavioral model of beef packing firms with an attempt to respect the regional scope of cattle markets.

"Dominant Firm Market Power in the Coconut Oil Export Market." David E. Bushena and Jeffrey M. Perloff (University of California, Berkeley)
Legal and institutional changes that increased concentration in the Philippine coconut oil refining and exporting industries enabled the Philippines to exercise dominant firm market power, raising the world price 150% above the competitive level. Reductions

in coconut oil demand because of health concerns will decrease Philippine export revenues.

"Performance in Canadian Food Manufacturing: An Industrial Organization Perspective." Tim Hazledine and Maingi Maundu (University of British Columbia)
The paper examines interindustry differences in profitability and in pricing between 4-digit SIC Canadian food and beverage processing industries. Two issues focused on are the impact of seller concentration results on market power and cost efficiency and the extent to which Canadian tariff protection creates rents which are dissipated in higher costs.

"Policy Analysis in an Imperfectly Competitive Market: A Conjectural Variations Model for the Food-Manufacturing Industry." Leo Maier (Cornell University)
The effects of government intervention are analyzed in a conjectural variations model of U.S. food manufacturing. The policy elasticities of the perfectly competitive model are valid predictors of policy effects irrespective of the type of oligopoly. Changes in the degree of competition may alter the magnitude of the policy elasticities.

Market Organization and Competitive Strategies in the Food Industries (Stanley Fletcher, University of Georgia, presiding)

"The Effect of Quality Changes and Limited Marketing Seasons on the Demand for Fresh Blueberries." Antonia L. Hoelper and Michele C. Marra (University of Maine)
This study examines the notion that fresh fruit prices follow a trend separate from that due to supply changes over the marketing season. Quality changes and a limited marketing season are hypothesized to contribute to changes in demand. The empirical results support the hypotheses in the Boston fresh blueberry market.

"A Dynamic Control Approach to Discerning the Potential for a Supply-Management Marketing Order for Southeastern Sweet Onions." W. T. Huang (National Ping-Tung Agricultural College) and J. E. Epperson (University of Georgia)
Dynamic optimal control was used to ascertain the potential effectiveness of a supply-control marketing order for southeastern sweet onions. A dramatic increase in producers' surplus relative to the free market case was evident from imposition of the order. However, the reduction in social welfare was noticeable.

"Vertical Coordination: A Transaction Cost Approach." Stuart D. Frank and Dennis R. Henderson (Ohio State University)
Vertical coordination has been shown to be superior to vertical integration as an element of industrial structure. In this paper, the effects of transaction costs on vertical coordination are investigated. The results confirm the theoretical expectation that transaction costs are the primary motivation for vertical coordination.

"An Oligopoly Model of a Vertical Market System." Kostas Karadininis and Murray Fulton (University of Saskatchewan)
Many agricultural markets are vertical systems with oligopolistic firms operating alongside smaller, more competitive, price-taking firms. Despite the prevalence of this structure, little theoretical modeling has been undertaken. The purpose of this paper is to develop a model that incorporates these aspects. The model is also used to examine countervailing power.

"Motives for the International Licensing of Branded Food and Related Products." Ian M. Sheldon and Dennis R. Henderson (Ohio State University)
Given initial empirical observations of international licensing of food and beer brands, this paper presents a simple game-theoretic model of the motives for licensing. The model suggests that imperfect competition in overseas markets and imperfect information about incumbent firms' payoffs are important determinants of a branded product licensing equilibrium.

Reexamining Conventional Wisdom on Common Property Resources and Water Demand (Robert Patrick, Colorado School of Mines, presiding)

"Migration as the Cause of Common Property." Greg Hertzler (University of Western Australia)
Migration, one of three fundamental ways a resource stock can change, makes a resource common property. This study models migration and the degree of common property along the continuum from exclusive access through limited access to open access. Most migratory resources will have limited access between the two extremes.

"On the Efficiency of Private Property: Reexamining the Empirical Evidence from the Oyster Grounds of the Chesapeake Bay." George D. Santopietro (Radford University) and Leonard A. Shabman (Virginia Polytechnic Institute and State University)
Agnello and Donnelley's analysis of the oyster industry has become the standard reference for evidence of the tragedy of the commons. In this paper, we explain why reestimation of their model with more recent data yields different results and explore why the economic profession has been so willing to accept Agnello and Donnelley's results.

"Beyond the Commons: Maryland's Oyster Industry." Ivar Strand, Douglas Lipton, and Amy Buss (University of Maryland)

Many economists argue that leasing common oyster grounds can prevent resource depletion. We argue that privatization must consider seed, not just submerged bottom. The history of Maryland's industry shows that the broodstock and shellstock are necessary elements in producing seed and hence must be considered in any privatization scheme.

"Information and the 'Optimal Control' of an African Rangeland Resource." Brent M. Swallow (University of Wisconsin) and Ray F. Brokken (International Livestock Centre for Africa)

A simple dynamic model of rangeland utilization is specified for the case of Lesotho. Lack of information regarding ecological relationships, investment strategies, exchange mechanisms, and resource management hamper the model's usefulness for determining the existence of open access or the potential impacts of alternative policy instruments.

"Municipal Water Demand: Evidence of Consumer Irrationality?" James Booker (Colorado State University)

Estimation of municipal water demand functions is complicated by nonuniform rate structures. Misspecification bias in using an income difference variable may be important in anomalous results reported in recent studies. Demand estimates using an alternative specification offer one interpretation of these results.

Soil Erosion and Water Quality: Can Economists Un-Muddy the Waters? (Richard Farnsworth, University of Illinois, presiding)

"Erosion Restrictions for Water Quality Improvement: Impacts of the Agricultural Sector." Marc O. Ribaudo (ERS USDA)

A soil-productivity-based erosion rate limit on cropland, imposed to improve surface water quality, would generate large erosion reductions at relatively low cost to producers and consumers. However, such a restriction would generally not result in regions characterized by high concentrations of sediment reaching a water quality goal.

"An Economic Assessment of 1990 Farm Bill Water Quality Options." C. Tim Osborn, Marc O. Ribaudo, and Ken Algozin (ERS USDA)

With greater attention being given to impact of agriculture on both surface and ground water quality, the 1990 farm bill debate is sure to include consideration of water quality programs. In this paper, the authors investigate the economic impacts of two land retirement programs similar in concept to the Conservation Reserve Program of the Food Security Act of 1985. Results indicated that expansion of the CRP to address surface and ground water quality issues is possible and would generate positive economic benefits for water users.

"Low Input, Sustainable Agriculture: Economic and Environmental Implications of Increased Alfalfa Production in the Eastern Corn Belt." John C. Foltz, Marshall A. Martin, and Jess Lowenberg-DeBoer (Purdue University)

Inclusion of alfalfa in crop rotations on Eastern Corn Belt farms with high and low productivity soils was analyzed with a mathematical programming model. Net incomes were larger with the government program but inclusion of alfalfa in the rotation reduced nitrogen fertilizer and herbicide use, potentially reducing environmental degradation.

"Erosion and Sediment Reduction Benefits of Conservation Compliance in an Agricultural Watershed." Tony Prato and Shunxiang Wu (University of Missouri)

Erosion and sediment reduction benefits are determined for resource management systems that maximize annual net returns in a northern Idaho watershed subject to achieving the erosion control standards established by conservation compliance. Net benefits are positive relative to conventional tillage but negative relative to reduced tillage.

"Off-site Sediment Damage Effects of the Conservation Reserve Program." Robert R. Alexander, Burton C. English, and Kurtis Hale (University of Tennessee)

One purpose of the Conservation Reserve Program is to reduce sediment and improve water quality. An interregional sedimentation model, the Micro-Oriented Sediment Simulator II, is used to evaluate the impact of the Conservation Reserve Program on sedimentation and on the offsite costs of sediment damage.

Evaluating Alternative Timber Management Objectives and Demand (Ilan Vertinsky, Director, University of British Columbia, presiding)

"The Roles of Finished Product Inventory and Price Expectations in the Softwood Lumber Industry." Jan K. Lewandrowski (RTD ERS USDA)

This paper presents a regional model of the U.S. softwood lumber sector. The firm's production, inventory, and sales behavior follow from a single optimization problem. Producers act based on inventories and rational price expectations. The demand for lumber is derived from the demands for new and remodeled houses.

"Timber Supply from Nonindustrial Private Forests: Reconsidering the Conventional Wisdom." Bill Provencher (University of California, Davis)
This paper challenges a bit of conventional wisdom by arguing that private forest owners who derive satisfaction from a variety of forest outputs may nevertheless manage their forests simply to maximize timber profits. A reexamination of regression analyses reported in the literature supports this argument. Policy implications are discussed.

"Solving the Aggregation Problem with Area-Frame Samples: The Analysis of New Land Use Policies." Ian Hardie (University of Maryland) and Peter Parks (Duke University)
The aggregation problem implicit in the production of regional land use response to new government policies may be solved using a random variable profit maximization model and area-frame sample data. Such a model is illustrated by predicting landowner and land use response to cost subsidization policies for pineland reforestation.

"The Economics of Plantation Forestry for Electrical Power Generation in Eastern Ontario." Brian P. Cozzarin, Wayne C. Pfeiffer, Glenn C. Fox, Andrew Gordon, and Willem van Vuuren (University of Guelph)
The question of whether intensively managed hybrid poplar and willow trees grown on a plantation can compete economically with coal and oil in generating electrical power was addressed. Break-even prices and the impact of key variables on them were determined for three management systems (*a*) short-rotation hybrid poplar, (*b*) minirotation hybrid poplar, and (*c*) minirotation hybrid willow.

Improving Efficiency in Irrigated Agricultural Water Use (Richard Gardner, State of Idaho, presiding)

"A Multicrop Production Model of Lands Served by the Bureau of Reclamation." Michael R. Moore (ERS USDA) and Donald Negri (Williamette University)
To analyze the issue of water conservation on cropland served by the Bureau of Reclamation, we develop a multicrop production model with water and land as fixed, allocatable inputs. Crop supply and land allocation equations are estimated for six regions. Elasticities with respect to the water constraint generally are inelastic.

"Production Functions of Western Irrigated Crops." Noel R. Gollehon and Michael R. Moore (RTD ERS USDA), Donald H. Negri (Willamette University)
For two functional forms, this paper reports econometric estimates of production functions for thirteen major irrigated crops using a common dataset and a consistent specification of the variables across crops. Estimates of the output elasticity of irrigation water are uniformly highly inelastic for each crop.

"Economic Feasibility of Contingent Water Markets for Columbia Basin Project Irrigated Agriculture." Philip Halverson and Norman K. Whittlesey (Washington State University)
A contingent water market is proposed for Columbia Basin Project irrigators as a means of supplementing Pacific Northwest firm energy supplies. Linear programming and stochastic simulation are used to estimate the increase in value of the region's firm power and the long-run impacts to irrigators' net farm income.

"Price Effects of Irrigation Technology Transitions in the Pacific Northwest." Glenn Schaible and C. S. Kim (ERS USDA), Norm Whittlesey (Washington State University)
Parks' modified multinomial logit (MML) model is applied to determine price effects on irrigation technology transitions in the Pacific Northwest. Parks' MML model accounts for the (standard) logit approximation error and for specification error. The results indicate elastic but relatively small price effects. Locational factors also affect technological transitions.

"Drought Insurance for Municipalities: Water Lease Options." Tariq S. Khokhar, Kim D. Dillivan, James J. Jacobs, and Larry J. Held (University of Wyoming)
Municipalities facing water shortages should consider the temporary transfer of water from irrigation to urban use. This paper analyzes the exercise cost of water lease options for Casper, Wyoming. The estimated cost of water lease options indicate a substantial savings to Casper when compared to the recommended alternative.

Economic Issues in Fishery Management and Demand (Daniel Huppert, University of Washington, presiding)

"Input Controls in a Fishery: Success or Failure?" Diane P. Dupont (University of Guelph)
This paper examines the effectiveness of input controls in a fishery in preventing rent dissipation. The paper uses duality techniques to define an elasticity that can measure input substitution possibilities in firms facing input controls. Data from the British Columbia salmon fishery show that controls have not worked.

"Seasonal Patterns and Regional Preferences for Salmon in Japan." Cathy Roheim Wessells (University of Rhode Island) and James E. Wilen (University of California, Davis)

Japanese demand for salmon plays a central role in the U.S. salmon fishery. In an effort to better understand the factors that influence the import demand, a system of retail demand equations was used to analyze intertemporal and regional patterns of consumption of salmon and other fish in Japan.

"Intraseason Regulation and Economic Efficiency in Recreational Fisheries: An Application to Pacific Salmon." Stephen K. Swallow (University of Rhode Island)
This paper focuses on efficient regulation of the within-season harvest process for recreational fisheries. Efficient allocation within a season can improve economic benefits, even though political or biological objectives determine the season's quota. The paper includes simulation results for setting creel limits in a hypothetical Pacific salmon fishery.

"An Hypothesis on the Role of Capital Markets in the Development of Brazil's Shrimp Aquaculture Industry." James R. Wilson and Roberto De Soussa Medina (Université du Québec à Rimouski)
Forty-nine Brazilian shrimp aquaculture firms were analyzed to determine the capital intensity of their operations, and the relation this had to financial health. This data plus the history of Brazilian shrimp aquaculture support the hypothesis that capital markets played a role in shaping aquaculture technology toward factors intensive in land/environmental goods.

"The Returns from Wetland Reclamation versus Preservation." W. van Vuuren and P. Roy (University of Guelph)
Private and social returns from wetland reclamation and from preservation are calculated. For both wetland reclamation and preservation the difference between social and private returns are large. From the viewpoint of society preservation is the best option, while from the owner's point of view reclamation gives the highest returns.

Benefit-Cost Analysis and Revealed Preference Approaches for Evaluating the Interface of Wildlife and Environmental Quality with Marketed Natural Resources (John Loomis, University of California-Davis, presiding)

"Hedonic Estimation of Implicit Price and Demand for a Louisiana Deer Hunting Lease Attribute." Mark L. Messonnier and E. Jane Luzar (Louisiana State University)
A hedonic framework is used to estimate the implicit price of a selected Louisiana deer hunting lease attribute, acreage available per member of a deer hunting club. A survey of 473 hunting clubs provides primary data for estimation of the hedonic price model specified in flexible Box-Cox functional form. The willingness-to-pay function for increased acreage per hunting club member is also empirically estimated, providing information on hunter willingness-to-pay to avoid congestion.

"Effects of Exhaustible Resource Exploitation on Renewable Resource Production: An Economic Analysis of Oil Development and Caribou." Uma Ganapathy and Stephen K. Swallow (University of Rhode Island)
Trade-offs between exhaustible resource development and losses in renewable resource benefits are examined by analyzing impacts of oil development on benefits from subsistence hunting of caribou in ANWR, Alaska. Losses in caribou benefits are evaluated by linking the environment's carrying capacity for caribou to the acreage allocated to oil development.

"Conjoint Analysis of Demand for Waterfowl Hunting." John Mackenzie and Benaifer R. Eduljee (University of Delaware)
This paper compares the conjoint measure approach with conventional contingent valuation methods. It develops a conjoint analysis of demand for waterfowl hunting as a composite of various trip attributes which are arguments in the utility function or the dual expenditure function. Marginal valuations of attributes, including travel time, are derived.

"Valuing Unpriced Quality Improvements from Observed Data: Southwestern Fishing." Frank A. Ward and Ibrahim Isytar (New Mexico State University)
A marginal benefits function defined over environmental characteristics is specified to be consistent with a flexible form utility index. The ordinary demand system from the utility index is estimated from observed data. Results from southwestern reservoirs reveal recreational water values ranging from $130 to $6,500 per acre foot.

"A Hedonic Analysis of Herbicides: Does Safety Matter?" E. Douglas Beach and Gerald A. Carlson (North Carolina State University)
Farmers may value water and user safety characteristics of herbicides as they select among producers to obtain weed control. Prices per application in the corn and soybean herbicide markets are explained by safety, market, and weed control characteristics. Leaching and user toxicity are statistically significant, but elasticities are small relative to some productivity characteristics.

Making Natural Resource Models More Realistic: Incorporating Risk, Uncertainty, and More Re-

alistic Assumptions (Murray Fulton, University of Saskatchewan, presiding)

"Resource Policy Analysis: Quality Control with Uncertainty." Donna J. Lee (University of Hawaii)
Random events often confound legislative efforts to achieve resource quality goals. Lack of sufficient information and risk-averse behavior can cause legislators to overinvest in control. This paper describes a new methodology for evaluating resource policy when the outcome is uncertain. Empirical results for water quality in a western river basin are presented.

"A Chance-Constrained Programming Analysis of Soil Conservation: An Examination of the Normality Assumption." Minkang Zhu and Daniel B. Taylor (Virginia Polytechnic Institute and State University), Randall A. Kramer (Duke University)
The rainfall erosion index, and thus soil loss, follows a lognormal rather than a normal distribution. The impacts of formulating a chance constraint on soil loss using a normal distribution, linearizing that constraint, and employing a lognormal distribution are assessed. Maintaining the normality assumption can bias the results.

"The Buffer Value of Groundwater with Stochastic Surface Water Supplies: The Case of a Confined Aquifer." Yacov Tsur and Ted Graham-Tomasi (University of Minnesota)
When utilized with a stochastic source of surface water for irrigation, groundwater may serve to mitigate fluctuations in the supply of water. The corresponding benefit is the buffer value of groundwater. We show that the buffer value is positive. Numerical studies reveal that its magnitude can be significant.

"An Economic Evaluation of Alternative Crop Management Systems Under Risk and Uncertainty in Prairie Agriculture." Randolph Seecharan, Shankar Narayanan, and V. O. Biederbeck (Agriculture Canada)
The study evaluates a selection of existing and alternative crop management systems in terms of their impact on sustainability of the soil resource base and on the economics of annual net returns, imposing risks, and uncertainty resulting from variability in rainfall, yields, and output prices in the Brown soil zone in Saskatchewan.

"Using Referenda for Natural Resource Investment Decision Making: Examining the Self-Interest Voting Model." Leonard Shabman and Kurt Stephenson (Virginia Polytechnic Institute and State University)
The self-interest model of voting behavior is used to analyze a single issue referendum for the approval and financing of a flood control investment in Roanoke, Virginia. Results indicate that some assumptions underlying the model are invalid. The implications of the model on natural resource decision making are discussed.

Policy Mechanisms for Environmental Control (John C. Bergstrom, University of Georgia, presiding)

"Water Markets and Water Quality." Marca Weinberg, James E. Wilen, and Catherine L. Kling (University of California, Davis); Zach Willey (Environmental Defense Fund)
A nonlinear programming model is developed to simulate grower response to water market scenarios. Significant reductions in drainage are predicted as a result of water conservation and improvements in irrigation efficiency, indicating the potential role of water markets as a policy tool for addressing the environmental problems of irrigated agriculture.

"The Effects of Consumer Demand on Regulation of Food Safety." Timothy H. Brown (University of California, Berkeley)
In a model where production inputs contaminate a homogenous food product, the demand response of informed consumers is compared to efficient regulation. Information changes the market failure from a health hazard among consumers to a common pool externality among competitive producers. Full information alone is not sufficient for efficiency.

"Incentives for Nonpoint Pollution Control." James S. Shortle (Pennsylvania State University)
Emissions-based instruments are inappropriate for nonpoint pollution. Two input-based incentive structures for nonpoint pollution control are presented. One is incentive compatible and obtains the efficient outcome. The second economizes on information but with a corresponding loss of efficiency.

"Marketable Pollution Permits with Incomplete Enforcement." Andrew G. Keeler (University of California, Berkeley)
This paper explores the effect of incomplete enforcement on pollution quantities and the number of complying firms in a pollution control system relying on marketable permits. Results indicate the possibility that pollution could be higher than under a comparable uniform standard and fewer firms might comply with their legal limits.

"Principles for Obtaining Optimal Emission Levels When Abatement Costs Are Private Information." Eirik Romstad (Norwegian Agricultural Economics Research Institute) and Olvar Bergland (Oregon State University)

A method of finding optimal emission levels when the regulatory agency does not know the individual firm's pollution abatement costs and firms are reluctant to reveal these costs is developed. The optimal emission level is where the emission permit market price equals the inferred price from the emission damage function.

Conceptual Issues in Value Measurement (John R. Stoll, Texas A&M University, presiding)

"Recreation Site Definition and Benefit Measurement." Raymond B. Palmquist and V. Kerry Smith (North Carolina State University)
The value of recreation site quality has become an important policy issue, yet the definition of a site is often unclear. This depends on aggregation issues within an individual's utility function. Empirical results show that relatively small changes in aggregation result in significant differences in value estimates for environmental improvements.

"Valuing Complex Policies with Contingent Valuation: Functional Forms and Estimation Procedures." John P. Hoehn (Michigan State University)
A valid contingent valuation design accounts for the substitutions that households make across policy components. Flexible functional forms are specified that allow one to estimate valid Bradford bid curves and to test for substitution effects. Estimates conform to theory. Results indicate that regional environmental conditions are strict substitutes in valuation.

"Testing the Fallacy of Independent Valuation and Summation in Multipart Policies: An Empirical Test of Whether Too Many Proposals Pass the Benefit Cost Test." John B. Loomis (University of California, Davis), John Hoehn (Michigan State University), and Michael Hanemann (University of California, Berkeley)
Statistical tests demonstrate the error of independent valuation and summation of related programs. Benefits of reducing farm drainage contamination and increasing wetlands in California would be overestimated by a factor of two if independent benefit estimates were simply summed. A more correct holistic valuation approach is demonstrated whereby respondents value packages of individual programs.

"Evaluating Use Benefits Under Uncertainty: Is There a 'Correct' Measure." Charles E. Meier and Alan Randall (Ohio State University)
This paper discusses the many "correct" measures of uncertain use benefits. The measures include expected surplus, option price, the willingness-to-pay focus, and the expected value of fair bet payments. Each measure's appropriateness depends upon both state-conditional pricing and insurance, whose roles are shown to be quite distinct.

"Uncertainty and Voluntary Contributions to Collective Risk Reduction Programs." Jason F. Shogren (Iowa State University)
Uncertainty has been shown to increase voluntary contributions to traditional public goods. This paper explores whether this result holds for collective risk reduction. Given risk is defined by probability and severity, and policy promoting voluntary provision of collective risk reduction will confront complexities which may render the effort ineffective.

Value Measurement and Confidence (Olvar Bergland, Oregon State University, presiding)

"Estimating External Costs of Municipal Landfill Siting through Contingent Valuation Analysis: A Case Study." Roland K. Roberts, Peggy V. Douglas, and William M. Park (University of Tennessee)
Contingent valuation was used to estimate external costs of siting a landfill in the Carter community of East Knox County, Tennessee. Estimates of annual external costs were $227 per household. Income, education, and perception of health risks were most important in determining a household's willingness to pay to avoid a landfill.

"Comparing Benefit Estimates from Discrete Choice Models for Contingent Valuation Surveys." Timothy Park (University of Nebraska) and John Loomis (University of California, Davis)
Mean willingness-to-pay estimates from a closed-ended contingent valuation survey are compared using the utility difference model suggested by Hanemann and a censored logistic regression model proposed by Cameron. Methods for deriving confidence intervals for benefit estimates from the two approaches are developed.

"Improvement in Estimation Efficiency and Precision of Benefit Estimates from Use of Double Bounded Dichotomous Choice Contingent Valuation." Michael Hanemann (University of California, Berkeley), John Loomis (University of California, Davis), and Barbara Kanninen (University of California, Berkeley)
The precision of willingness-to-pay estimates can be improved by asking each respondent two linked dichotomous choice questions rather than one. The two responses are used to estimate a double-bounded logit equation. An empirical analysis shows the confidence interval on the benefit estimates is substantially tightened using the doubled bounded logit approach.

"Valuing Environmental Quality Changes Using Averting Expenditures: An Application to Groundwater Contamination." Charles W. Abdalla and Brian A. Roach (Pennsylvania State University)
The averting expenditures method for valuing environmental quality changes offers a means for generating theoretically sound benefit estimates, yet it has received little empirical application. This paper reviews the theoretical basis for averting expenditures and presents the results of an application to groundwater contamination.

"Measuring Willingness to Pay for Nonmarket Goods." Douglas M. Larson (University of California, Davis)
The change in expenditure with changes in nonmarket goods like environmental quality can be obtained from empirical demand systems whether or not preferences are weakly complementary. The separability structure usually assumed in empirical work can be exploited instead. This makes possible measurement of use and nonuse values of environmental resources.

Environmental Issue and Water Resources (Teofilio Ozuna, Jr., Texas A&M University, presiding)

"An Integrated Model of Surface and Ground Water Quality." Richard J. Brazee and Stephen R. Crutchfield (ERS USDA)
The off site of agricultural chemicals and soil erosion on surface and ground waters are incorporated in an integrated model of agricultural production. The interdependencies of ground and surface water quality are highlighted. The effectiveness of chemical use and soil erosion restrictions in protecting water quality are compared and contrasted.

"Overview and Analysis of Recent State Initiatives in Pesticide Regulation for the Control of Groundwater Contamination." Sherry Wise and Stanley Johnson (Iowa State University)
Various states have been active in regulating pesticides to control groundwater contamination. An overview of recent state initiatives in pesticide regulation is presented. Trends show increased use of regulations that reduce pesticide user's property rights. Tobit analysis shows the influence of various political, economic, and physical factors on the legislation.

"Relating Qualitative and Quantitative Evaluations of Collective Risks: The Case of Drinking Water Contamination." Donald J. Epp and Brian Roach (Pennsylvania State University)
A matrix of numerical risk statements and qualitative ratings was presented to respondents producing numerical equivalents for qualitative ratings of water contamination risk. There was general correspondence between risk magnitude and related seriousness, but large variance in qualitative ratings of numerical risks renders some of the variables derived statistically insignificant.

"An Empirical Study of the Welfare Effects of Climate Change on World Agriculture." John Reilly, James Tobey, and Sally Kane (ERS USDA)
Previous studies of the economic effects of climate change on agriculture in individual countries have been largely limited to domestic yield effects. Using a model of world agricultural trade, we evaluate the changes in economic surplus when climate change directly alters domestic agricultural yields, and indirectly alters world trade.

"The Effect of Commodity Programs on Fertilizer and Pesticide Use in Agriculture." Glenn A. Helmers and Azzeddine Azzam (University of Nebraska)
A one output-seven input equilibrium model of U.S. agriculture was developed to study commodity program alternatives. The present program (land retirement and target prices) was compared to decoupling or free markets, an output quota, and modifications of the existing program. The results demonstrate that commodity programs have a very strong impact on the use of fertilizer and pesticides in agriculture.

Quantitative Methods and Public Policy I (Richard Howitt, University of California, Davis, presiding)

"Alternative Empirical Measures of the Supply Effect of the Corn Price Support Program." Frank M. Howland (Wabash College)
A methodology for measuring the supply effect of price support programs on individual farms is developed and empirically implemented on a sample of 104 Illinois farms, observed over the period 1976–85. The supply effect measures require less restrictive assumptions than analyses based on aggregate time-series data.

"Modeling the U.S. Grains Programs: A Microeconomic Approach." Marinos E. Tsigas, Thomas W. Hertel, and Paul V. Preckel (Purdue University)
A framework is presented for analyzing the impact of U.S. grains programs. The model's advantages are its endogenous treatment of the participation decision and the recognition of producer heterogeneity. The estimated model predicts that the 1986 freeze on program payment yields for wheat increased returns to land.

"An Application of Neutral Networks in Predicting Planted Acreage of Corn and Wheat in the United States." J. William Uhrig (Purdue University) and Clayton Jay Botkin (The WEFA Group, Inc.)
Corn and wheat planted acreages are analyzed using a trained neutral network consisting of highly parallel, interconnected processing elements. Network training was accomplished by presented examples to the network corresponding to actual input-output data sets.

"Gibrats' Law and Farm Growth in Canada." Murray E. Fulton and J. Stephen Clark (University of Saskatchewan)
This paper develops a model where firms' growth rates can be autocorrelated without violating Gibrats' Law. The test of Gibrats' Law is shown to be a unit root test. Using data for the prairie region of Canada, we find that Gibrats' Law is not rejected.

"An Econometric Model of Government Intervention in the Dairy Sector." Donald J. Liu (Iowa State University); Harry M. Kaiser, Timothy D. Mount, and Olan D. Forker (Cornell University)
In the dairy market, two regimes are possible: a competitive regime occurs when the market price exceeds the support price, and a government regime occurs otherwise. This paper presents and tests an econometric framework for estimating a two-regime structural system for the dairy industry.

Quantitative Methods and Public Policy II (Thomas Spreen, University of Florida, presiding)

"Modeling Policy Design and Imperfect Competition: The General Stackelberg Case." Anoush Farhangi and Paul V. Preckel (Purdue University)
Models of optimal policy design and imperfect competition are formulated as bilevel programming problems. The general bilevel programming problem is then reformulated as a single nonlinear complementarity problem. The reformulation is illustrated for two examples of market equilibrium problems with imperfect competition employing Stackelberg leader-follower behavior.

"The Impact of Regional Trade Liberalization on National Food Security: The Case of Senegal." Ousmane Badiane (International Food Policy Research Institute)
Regional trade liberalization has been proposed as a means of improving food security in Sahelian West-Africa. A general-equilibrium model is used to stimulate its impact on level and stability of food consumption in Senegal. It concludes that liberalizing food trade stabilizes food consumption but does not raise its level.

"Implicit Additivity as a Strategy for Restricting the Parameter Space in CGE Models." Thomas W. Hertel (Purdue University), Everett B. Peterson (Virginia Polytechnic Institute and State University), Yves Surry (Agriculture Canada), and Paul V. Preckel (Purdue University)
The purpose of this paper is to illustrate the value of the constant difference elasticity (CDE) functional form in applied general equilibrium analysis. It is a natural generalization of the commonly used CES form which permits the researcher to calibrate a model to complete vectors of own-price and income elasticities.

"The Welfare Significance and Non-Significance of General Equilibrium Demand and Supply Curves." Walter N. Thurman (North Carolina State University)
In certain circumstances, surplus measures behind general equilibrium supply and demand curves measure welfare changes from several markets. However, when there is feedback through both demand and supply channels, only the welfare triangle constructed from the curves has welfare significance; the surplus areas behind the curves do not.

"The Obsolescence of Social Cost-Benefit Analysis? Libertarian Pull and Socialist Drift." G. C. Van Kooten (University of British Columbia)
This paper argues that social cost-benefit analysis is buffeted by theories of political philosophy and social justice that threaten its usefulness and acceptance. One such theory is responsible for "socialist drift" in project evaluation procedures; the other denies government a role in the economy, thereby seeing no need for project evaluation.

Econometric Methods (Richard Boisvert, Cornell University, presiding)

"Bootstrap Confidence Intervals for Flexibilities Derived from Linear Equations." Teofilio Ozuna, Jr., and Andrew Tan (Texas A&M University)
Efron's Bootstrap is proposed as an alternative method for constructing confidence intervals for flexibilities. An empirical illustration is presented and it points out potential pitfalls when using Fieller's confidence interval method. The bootstrap is quite easy to implement and can be extended to more sophisticated and complete demand/supply equations.

"Confidence Intervals for Elasticities and Flexibilities." Jeffrey H. Dorfman (University of Georgia), Catherine L. Kling and Richard J. Sexton (University of California, Davis)
This paper examines methods for constructing confidence intervals around elasticity and flexibility point estimates, including three bootstrap-based approaches, a Taylor's series approximation, and ap-

proaches proposed by Fieller and Scheffe. Results show that all methods except Scheffe's worked reasonably well, but the Fieller and Taylor's series methods outperformed the bootstrapped-generated intervals.

"Symmetry and Small Samples: Impacts of Theory and Data on Estimation." Abiodun Ojemakinde (Albany State College) and Mark D. Lange (Louisiana State College)
Applications of duality have contributed greatly to our understanding of the agricultural production sector. However, most studies suffer from problems of finite samples and restricted estimation with unknown covariances. The resulting standard errors from the estimation are understated. Bootstrapping standard errors is analyzed as an additional estimation improvement.

"Measurement Error and Proxies: An Empirical Assessment." John G. Lee and Hector O. Zapata (Louisiana State University), Kent Lanclos (Purdue University)
Aggregate economic time series and proxy variables are likely to be troubled by systematic measurement error; however, the effect of such errors on estimated model results is infrequently considered. A diagnostic procedure is introduced and applied to a trade model. Results from the application indicate that the error in variable problems is relevant.

"Cointegration and Causation: Some Monte Carlo Results." Hector O. Zapata (Louisiana State University)
Performance of the Direct Granger test is examined under integrated and cointegrated models in a Monte Carlo framework. The nature of the long-run equilibrium relationship affects test performance and sensitivity to sample size. Granger causality testing without cointegration analysis may result in mixed, and unexpected, outcomes.

Topics in Quantitative Methods (Garth Holloway, Purdue University, presiding)

"Forecasting in the Presence of Structural Change: An Analysis of Cattle Prices with a Gradual Switching VAR System." Barry K. Goodwin (Kansas State University)
A multivariate gradual switching VAR system is used to model structural change in the cattle industry. The model is used to generate forecasts which are superior to those obtained from standard VAR and univariate models. Impulse responses indicate that cattle prices have become much quicker to adjust to new information.

"A Reappraisal of the Box-Cox Methodology." Octavio A. Ramirez and J. S. Shonkwiler (University of Florida)
This study establishes that the function currently used as a basis for implementing the Box-Cox methodology is not a valid probability density function. Simulation evidence documents that the original Box-Cox approach can result in considerable bias.

"A New Estimation Approach Using Alternately Actual and Synthesized Observations: Application to a Quarterly Cow Inventory Model." Bruce L. Dixon and John W. Goodwin (University of Arkansas), Danny R. Pippin (Tennessee Co-op Extens. Service)
An efficient method for estimating regression parameters when observations on the dependent variable are alternately actual observations and synthesized observations is developed. A quarterly cow inventory model is estimated using this technique. Increases in real, short-term interest rates are shown to have had a major impact on cow inventories.

"Analyzing Complex Dynamic Bioeconomic Systems Using a Simulation Optimization Technique." Richard F. Kazmierczak, Jr., and George W. Norton (Virginia Polytechnic Institute and State University)
A hybrid approach to optimizing high dimension, complex dynamic systems is introduced. The method employs discrete computer simulation and maximum principle conditions to optimize nonanalytic deterministic or stochastic systems. Application is demonstrated with a policy problem in the area of pesticide regulation and the management of pest resistance.

"Stochastic Optimal Control for Agricultural and Resource Economists." Bruce A. Larson (ERS USDA)
This paper analyzes the optimum control of stochastic processes. An investment model is used to introduce stochastic differential equations, interpret Ito's lemma, and derive Bellman's equation. An economic model of soil conservation where erosion is a stochastic process is then used to derive and interpret the stochastic maximum principle.

Food Aid: Motives and Impacts (Carl C. Mabbs-Zeno, ERS USDA, presiding)

"Food Aid and Food Security: A Cautionary Note." Derek Byerlee and Daphne Taylor (CIMMYT)
A simple model is presented to examine the effects of instability in global food aid supplies on foreign exchange expenditures and food availability in recipient countries. When global food prices rise, food aid

recipients are doubly affected through (*a*) decreased availability of food aid and (*b*) higher costs of additional commercial imports needed to make up the shortfall.

"Urbanization and Food Imports in Sub-Saharan Africa." James Tabi, Wayne H. Howard, and Truman Phillips (University of Guelph)
Granger causality was used to determine the relationship between total food imports/food aid and urbanization. Urbanization Granger caused total food imports in thirteen of the twenty-four countries, while food imports caused urbanization in three countries. Food aid, however, caused urbanization in sixteen of the twenty-four countries.

"A Note on the Income Effects of P.L. 480 Food Aid." Richard Ball (University of California, Berkeley)
Previous studies have claimed that PL 480 imports might have little effect on food prices, because food aid receipts increase real income, and hence shift out the demand curve. This paper shows that, by reducing producers' incomes, food aid imports may actually decrease aggregate income, and therefore depress food prices.

"Is there an Alternative to Famine Relief?: An Example from the Sahel." Meredith J. Soule (University of California, Berkeley) and Gerald C. Nelson (University of Illinois)
Aid agencies spend large sums to provide famine relief and are typically unwilling to provide project support for long periods. Yet, in at least one case in the Sahel, it would be cheaper to provide a long-term subsidy for an existing irrigation project than to provide periodic famine relief.

"Donors, Institution Building, and a Sense of Strategy: Relieving the Constraint." John J. Waelti (University of Minnesota)
Donor efforts to assist third world educational institutions fail to address the fundamental constraint, a shortage of faculty resources with which to conduct basic teaching and research. Donors could address that constraint through augmented staffing, using funds to top off indigenous positions staffed by expatriates.

Technology Adoption and Applied Research Impact on Agricultural Productivity (Christina H. Gladwin, University of Florida, presiding)

"The Technology Adoption Process in Subsistence Agriculture: The Case of Cassava in Southwestern Nigeria." Rudolph A. Polson and Dunsten S. C. Spencer (International Institute of Tropical Agriculture)
A dichotomous choice model is used to analyze factors affecting the adoption of improved cassava (Manihot esculenta, Crantz) variety (TMS 30572) by subsistence multicrop producers in the humid rainforest ecology of southwestern Nigeria. Implications of the empirical results for agricultural extension policies in this agroecology are discussed.

"Biological Diversity and Technology Adoption in Andean Potato Agriculture." Stephen B. Brush, J. Edward Taylor, and Mauricio R. Bellon (University of California, Davis)
Biological diversity in cradle areas of crop origins is an important source of genetic resources for world agriculture. Econometric findings from Peru indicate that adoption of high-yielding potato varieties results in reductions, but not complete loss of, biological diversity on farms. Farmer planting decisions may complement off-site conservation methods.

"Identifying the Relationship between Agronomic Research and Changes in Producers' Surplus." Greg Traxler (CIMMYT)
A framework for evaluating agricultural research is presented and tested using a case study from the Yaqui Valley, Mexico. The model's ability to capture the impact of both applied and adaptive research efforts makes it a potentially useful tool for assisting research administrators to allocate resources.

"Why Do Peasants Appear Sluggish in Spite of a Hectic Life?" Alain de Janvry (University of California, Berkeley), Marcel Fafchamps (Stanford University), and Elisabeth Sadoulet (University of California, Berkeley)
Using a peasant household model, this paper shows that market failures can be responsible for the low price elasticity of cash crop production; for internal instability in peasants' work effort and food consumption; and for the role of consumer goods availability, taxes, and technological change in inducing cash crop production.

"An Economic Analysis of Technological Adoption in Swaziland." Ganesh P. Rauniyar and Frank M. Goode (Pennsylvania State University)
This study investigates the socioeconomic determinants of adopting technological packages in Swaziland. Factor, cluster, discriminant, and logit analyses were used. The results indicate that three technological packages and four farmer classes exist. Access to funds to purchase inputs and information regarding improved cultivation methods were the most important explanatory variables.

Food Policies: Projects, Reforms and Analyses (Roberta Van Haeften, OICD USDA, presiding)

"Incorporating Nutrition into Agricultural Development Projects." Pat Graham (University of Northern Colorado)
Although opportunity exists in agricultural projects to incorporate nutrition objectives, nutrition is frequently overlooked in applied economic development. Neglect is caused by the complexity of malnutrition and a lack of methodology. By amending the planning process, nutrition can be made an explicit objective in conjunction with other development goals.

"Food and Agricultural Policy Reform: The Case of Venezuela." Barry Krissoff (ERS USDA) and Paul Trapido (Inter-American Development Bank)
The Venezuelan government has taken the first steps towards agricultural policy reform. Based on simulation experiments, we find that the removal of support, mainly in grains, leads to greater dependence on imports of corn, sorghum, and rice, but lower feed grain prices spur production and exports of meats.

"The Costs of Indonesian Sugar Policy: A Policy Analysis Matrix Approach." Gerald C. Nelson and Martin Panggabean (University of Illinois)
Indonesian sugar policy is a complex web of contradictory policies, including mandatory production requirements, price supports, and input subsidies. The policy analysis matrix is used to measure the efficiency of sugar production in irrigated and dryland areas and to identify the distribution of resource transfers.

"The Poultry Industry as an Endogenous Factor in Mexican Agricultural Policy: A Neoclassical Approach." Lovell S. Jarvis (University of California, Davis) and C. Federico Perali (University of Wisconsin)
Rising demand for chicken in Mexico is alleged to have increased sorghum production and imports, thereby contributing to lower corn production and higher corn imports and prices. Because corn is consumed by the poor, a "food versus feed" controversy has emerged in Mexico. We model and empirically analyze this issue.

"A Goal Programming Evaluation of the Fisheries Development Plan for Sri Lanka's Coastal Fishing Fleet, 1988–1991." Palitha Muthukude (Govenment of Sri Lanka), James L. Novak and Curtis Jolly (Auburn University)
The ad hoc nature of selecting targets and resource allocations has been cited as the major reason for consistent underachievement of Sri Lanka's fisheries development plans. To overcome these shortcomings, this study used goal programming to optimize the achievement of fisheries development goals for the planning period 1988–91.

Agricultural Technology: An Assessment of Economic and Financial Constraints and Risk Management (Donald R. McDowell, North Carolina A&T State University, presiding)

"The Impacts of Capital and Land Constraints on the Economics of New Livestock Technology in Western Kenya." Fanny B. Nyaribo (Winrock Foundation) and Douglas L. Young (Washington State University)
Land constraints prevented the smallest modeled farms in a western Kenya region from benefitting from new forages, milk marketing improvements, credit, or goat management assistance. Expanded credit, however, permitted modeled medium and large farms to vigorously exploit these innovations; credit also expanded income more than did goat management improvements.

"A Modern View of Joseph's Policy: Food Stocks as Financial Assets." Peter Berck and Irma Adelman (University of California, Berkeley)
Buffer stocks are financial assets and should compete with other financial assets for scarce investment funds. We use the consumption-based capital asset pricing model to evaluate the desirability of holding stocks in an LDC versus the United States. Results are presented for eighteen LDCs.

"The Structure and Importance of Informal Financial Groups in Cameroon." Gertrud Schrieder and Carlos E. Cuevas (Ohio State University)
Based on a 1988 survey, this paper shows that informal groups in Cameroon are capable of responding to widely different demands for financial services. The striking importance of these informal groups in Cameroon highlights the need to consider the likely effect on these groups of financial policy measures.

"Farmer Risk Management Strategies: The Case of the West African Semi-Arid Tropics." Patricia Kristjanson (Abt Associates, Inc.) and Peter J. Malton (WARDA)
This paper sets out a conceptual framework to identify and analyze risk management practices employed by farmers in the West African semiarid tropics. Primary farm-level data from Burkina Faso are used to illustrate the approach. Implications for the design of new production technologies and policy formulation are discussed.

"Analyzing the Effects of New Technologies on Risk Using On-Farm Trials in Dryland Agriculture." E. Loehman, D. Ngambeki, Z. Yu, and R. Deuson (Purdue University)
In formulating objective functions for farm models in a risk context, historical data have been weighted equally to represent weather and cross-sectional risk,

thus relying on long time series rarely available in developing countries. A method is proposed to measure risk associated with new technologies introduced in Cameroon in 1984–87.

International Trade, Debt and Economic Development (Magid Dager, University of Arkansas, presiding)

"Will the Latin American Countries Ever Pay Their Debts?" John Baffes and Robert G. Chambers (University of Maryland)
The 1980s have been characterized by major borrowing levels of the Latin American countries. A common question asked by the creditors is whether those countries will be able to pay their debts back. This paper gives an answer to this question by utilizing the theory of cointegration. The results show that the countries examined have violated their borrowing limits.

"Cereals Protection and Agricultural Development Strategy in the Sahel." Christopher L. Delagado (IFPRI)
The stagnation of Sahelian agriculture under seemingly unchangeable exchange rates has led to calls for supporting growth and food security through protection of cereals. It is argued that this will harm both objectives by ignoring the true comparative advantage of the region in livestock and other exports to the coast.

"Analyse du commerce extérieur agricole de l'Afrique de l'Ouest théories économiques et évidences empiriques." Sylvain Lariviere and Frédéric Martin (Université Laval)
Les théories économiques des avantages comparés et de la dépendance fournissent des éléments d'explication de la structure du commerce extérieur agricole de l'Afrique de l'Ouest. Cependeant, leur caractère parfois simpliste et réducteur explique les écarts existants entre les prévisions de ces théories et l'évidence empirique.

"Trade Determinants as Sources of Economic Growth: An Empirical Inquiry." Thomas L. Vollrath and Paul V. Johnston (ERS USDA)
Trade specialization patterns generally correspond to the stages of development explanation of growth. Commercial policy distortions and factor intensity reversals explain why trade does not always fit the skilled labor continuum. Calculated income elasticities with respect to openness imply that economies become less dependent on international markets as they grow.

"Developing Countries' Performance in High-Value Product Trade." Mary E. Burfisher and Margaret Missiaen (ATAD ERS USDA), Allen Blackman (University of Texas, Austin)
This analysis of the high value agricultural exports of thirty-five LDCs to the OECD during 1970–87 concludes that LDCs can benefit from a shift to high value, but not necessarily processed, agricultural exports. Favorable supply factors have become more important in determining successful export performance.

Modeling the Diverse Factors Influencing Agricultural Development (Donald W. Larson, Ohio State University, presiding)

"Control in a Dynamic Local Economy: Modeling the Behavior of the Chinese Village Leader." Scott Rozelle and Richard N. Boisvert (Cornell University)
Village leaders in the Chinese reform economy are assumed to maximize a multiple-attribute utility function; their behavior is modeled in a dynamic control framework. Structural and control equations for five industrial and agricultural variables are estimated. Results confirm hypotheses that village leaders are preoccupied with rural industrialization but must maintain high agricultural productivity.

"A Temporary General Equilibrium Framework for the Analysis of Macroeconomic Influences on Agriculture in Sudan." Rashid Hassan (CIMMYT), A. Hallam (Iowa State University), and B. D'Silva (USDA)
Unfavorable macroeconomic conditions have been blamed for the failure of devaluations and liberalization to correct the bias against agricultural exports in Sudan. A general equilibrium model, with an endogenous money creation mechanism, is constructed to analyze macroeconomic linkages to agriculture. Stronger economic performance is achieved when exchange rate adjustments are supported with monetary control and less indirect taxation.

"Agrarian Structure and Internal Migration in Ecuador." Ricardo E. Quiroga and Boris E. Bravo-Ureta (University of Connecticut), Jorge Brea (Central Michigan University)
A logistic regression model is formulated to study internal migration in Ecuador. The results indicate that the individual's decision to migrate is significantly affected by agrarian structure variables such as land reform, population pressure, and land inequality. Also, expected income differentials and personal attribute variables significantly determine labor mobility.

"Optimal Service Area Under Stochastic Inflow Conditions: Medium-Scale Irrigation in Thailand." Sam H. Johnson, III (University of Illinois)

Chance-constrained programming is used to determine optimal service area for a reservoir in Thailand. Present design includes wet and dry season service areas of 3,371 hectares. The optimal design is an area of 2,192 hectares for the wet season with extensive canals and 1,179 hectares using intensive canals for dry season crops.

"Examining the Optimal Use of Cereal Grain and Straw in the Mafraq Farming Region of Jordan with a Mixed Integer Programming Model." David W. Hughes, Walter Penaranda, and Walter R. Butcher (Washington State University); Abdulla Jaradat (Jordan University of Science & Technology)

Grazing in lieu of harvest is an important decision for dryland crop and livestock farming in the Middle East. The harvest versus graze decision and the use of cereal grains and straws is examined with a mixed-integer programming model. The harvest decision is relatively insensitive to changes in key variables such as levels of alternative feed sources.

Modeling Agricultural Product Trade (Catherine Halbrendt, University of Delaware, presiding)

"Oligopsony in Wheat Trade." Utpal Vasavada (Université Laval)

The hypothesis that importers possess market power in the international wheat market is evaluated with data on market shares. A two-stage budgeting algorithm is proposed to account for departures from perfect competition. This methodology generalizes the celebrated Armington model. Techniques to estimate import demand functions and test hypotheses are discussed.

"Price Dynamics in International Wheat Markets." Ted C. Schroeder and Barry K. Goodwin (Kansas State University)

Vector autoregressions are used to evaluate dynamic relationships among prices in six important international wheat markets. The effects of freight rates and exchange rates are also considered. The results indicate that Canada is the dominant market, supporting views which assume an oligopolistic price leadership role for Canada.

"Determinants of the World Wheat Trade: An Application of the Gravity Model." Won W. Koo (North Dakota State University) and David Karemera (Wayne State University)

A gravity model is applied to the world wheat market to analyze trade flows of wheat. The study reveals that production capacities, national income, import and export unit value indexes, and trade policies (long-term agreement and credit sales) play an important role in determining trade flows of wheat in the 1980s.

"An Investigation of International Trade in a Processed Agricultural Product: The U.S. Import Demand for Wheat Gluten." Francois Ortalo-Magne (Purpan Graduate School of Agriculture) and Barry K. Goodwin (Kansas State University)

This paper discusses the international market for wheat gluten, an important protein supplement in processed grain products. An econometric analysis of the U.S. import demand for wheat gluten is undertaken. The price of flour, income, and domestic protein supplies are found to be important determinants of wheat gluten imports.

"Import Demand for U.S. Fresh Apples in Three Pacific and One European Markets." Amy L. Sparks (ERS USDA), James L. Seale, Jr. (University of Florida), and Boyd M. Buxton (ERS USDA)

U.S. apple producers in recent years have increased production, while domestic consumption levels have remained stable. Accordingly, exports of apples will become increasingly important. The system-wide approach to import allocation provides insights into U.S. competitiveness in four of its major export apple markets.

Tariffication and Other GATT Issues (Barry Goodwin, Kansas State University, presiding)

"Tariffication with Imperfect Competition: The Case of the Canadian Chicken Market." Giancarlo Moschini and Karl D. Meilke (University of Guelph)

In order to improve market access following the Uruguay Round of trade negotiations the United States has proposed that all nontariff barriers be converted to these tariff equivalents and then lowered over a transition period. This paper explores the implications of "tariffication" for the Canadian broiler chicken market, an interesting case study because tariffs and quotas are not equivalent policies in markets characterized by imperfect competition.

"An Economic Analysis of the Impact of Removing U.S. Import Quotas on Dairy Products." Steven A. Neff (ERS USDA)

Many GATT members object to the 1955 waiver granted exclusively to the United States. Under its authority, the U.S. maintains import quotas on dairy products. The paper uses multicommodity comparative statics simulations to evaluate three alternative policies, finding an equivalent tariff more feasible than deficiency payments or a free market.

"Calculating Protection Coefficients: Is it Always Appropriate to Use World Reference Prices?" Derek Byerlee and Michael L. Morris (CIMMYT)

Protection coefficients are usually calculated using world reference prices. Under certain conditions, world

reference prices do not represent a good approximation of the prices that would prevail in the absence of market distortions. Data from Pakistan illustrates how failure to consider these conditions can result in misleading policy recommendations.

"Is the PEG a Viable Option? A Look at Long-Run Issues." Bruno Larue and James Oxley (University of Guelph)
The Producer Entitlement Guarantee has been offered as a viable scheme which will provide support for agricultural producers and not be trade distorting. This paper addresses the assignment and long-run adjustment issues in allocating PEG levels internationally and offers an alternative manner of monitoring for trade distorting PEG levels.

"Tariffication: Issues, Concepts, and the European Community." Walter H. Gardiner and Mary Lisa Madell (ERS USDA)
"Tariffication," essentially the replacing of quantitative restrictions with equivalent tariffs, was originally included in the 1988 U.S. proposal to the negotiating group on agriculture in the current round (Uruguay) of multilateral trade talks. This paper presents the concept, the issues and an application to the EC wheat market.

Macroeconomic Linkages and Price Formation (Patricia Lindsey, Oregon State University, presiding)

"An Alternative Analysis of Smuggling." James Oxley and Bruno Larue (University of Guelph)
Analysis of the welfare effects of smuggling have been based on the traditional trade theoretic model. It is shown that this method may be inappropriate. An alternative framework is developed using a welfare function approach.

"World Price Variability versus Protectionism: A Causality Analysis." Isabelle Miramon and Bruno Larue (University of Guelph)
This paper analyzes the causal relationship between world price variability and protectionism in the agricultural sector, by testing for Granger causality for eleven commodities. Two definitions of price variability are used, and protectionism is measured by the level of PSEs for each commodity over the period 1979–88.

"Deviation of Relative Agricultural Prices from the Short- and the Long-Run Equilibria." Mark Denbaly (NEH ARED ERS USDA)
Important policy implications of relative agricultural price movements have resulted in much analyses regarding the deviations of relative prices from their equilibrium levels in the 1980s. Using two alternative definitions of equilibrium, two models which account for the cause of deviations are developed and statistical procedures for estimations are proposed.

"Macroeconomic Policy and the Real Exchange Rate in Jordan: Implications for Vegetable Exports." Curtis E. Youngblood (Sigma One Corporation) and Grant M. Scobie (SER/Sigma One Corporation)
The effects of real exchange rate changes on vegetable exports from Jordan are estimated. We model the linkage between monetary, exchange rate, and fiscal policies on the real exchange rate. We estimate the extent of real exchange rate appreciation under fixed exchange rates in the presence of high domestic inflation. This creates disincentives to vegetable exports.

"Relative Uncertainty of Price and Output in Farm and Nonfarm Sectors." Doo Bong Han and Dennis W. Jansen (Texas A&M University)
Uncertainty about inflation, nonfarm output growth, and farm output growth are analyzed using the multivariate GARCH-M model. The results indicate that only uncertainty about nonfarm output has real effects. However, farm output growth is not affected by uncertainty about nonfarm output growth.

Analysis of Bilateral and Multilateral Trade Agreements (Harold Von Witzke, University of Minnesota, presiding)

"The Effects of the Canadian–United States Free Trade Agreement on Bilateral Trade Flows of Agricultural and Industrial Products." Ihn H. Uhm (Canadian International Trade Tribunal) and Won W. Koo (North Dakota State University)
A bilateral trade model is developed to evaluate impacts of the Canadian–United States Free Trade Agreement on trade flows of agricultural and industrial products between the two countries. This study found that the FTA would increase trade flows between the two trading partners, primarily through reductions of their import prices and increases in income levels. Exchange rate movements, however, would be a key parameter in determining the bilateral trade flows during the post-FTA era.

"US–EC Proposals for Long-Term Agricultural Reform in the Uruguay Round of GATT Negotiations: Will Minor Modifications in Agricultural Support Rates Lead to the Final Agreement? Glenn C. W. Ames (University of Georgia)
A world net trade model was used to evaluate the implications of partial price support reduction in the United States and European Community. Results were compared with complete multilateral trade liberalization and U.S. and EC proposals for long-term ag-

ricultural reform in the Uruguay Round of GATT. Wheat trade declined more than other commodities under both scenarios.

"U.S. and Canada FTA and Its Agricultural Economic Ramifications." C. Thomas Worley (Washington State University) and Dean Baldwin (Ohio State University)
The U.S.–Canada Free Trade Agreement (FTA) should increase economic welfare and specialization in agriculture for both nations. Producers and regions that are most (least) competitive may benefit (lose). Resources are reallocated among industries and regions. A quadratic program quantifies these issues for the short term and long run for both nations.

"U.S. Sugar Policy: A Welfare Analysis of Policy Options Under Pending Caribbean Basin Expansion Act Legislation." William A. Messina, Jr., and James L. Seale, Jr. (University of Florida)
A welfare analysis of two U.S. sugar import quota policy options was conducted. Results indicate that relaxing U.S. quotas to Caribbean Basin sugar-exporting countries would generate net domestic gains and gains to these countries, potentially in excess of those provided by the entire Caribbean Basin Initiative.

"1990 Farm Bill and Developing Countries." Liana C. Cuffman Neff (ERS USDA)
The 1990 Farm Bill will affect world markets and thereby will affect developing countries (LDCs). Projections of how world food markets might change in 1991/92 in three policy options show that with increased openness of U.S. agricultural markets, aggregate world prices increase and LDC agricultural trade balance improves.

LDC Debt and Market Structure Issues (Gerald C. Nelson, University of Illinois, presiding)

"The Competitive Structure of U.S. Agricultural Exports." Daniel H. Pick (ATAD ERS USDA) and Timothy A. Park (University of Nebraska)
The competitive structure of agricultural exports from the United States is examined using a model of export behavior based on pricing decisions across destination markets. The hypothesis of price discrimination is rejected for cotton, corn, soybeans, and soybean meal. Strong evidence against competitive market structure is obtained for wheat.

"Random Weather Shocks and Biased Estimates of Excess Demand." B. Stephen Labson (University of California, Berkeley)
In an excess demand system where random weather shocks enter multiplicatively, rather than additively, estimates of the underlying parameters will be inefficient under the "small country" assumption and biased in the "large country" case. A Monte Carlo simulation demonstrates that the magnitude of the bias is potentially very large.

"Empirical Investigation into the Effect of Financial Stress on Trade Flows for Selected Caribbean and Latin American Countries." Maria Veronica Gottret, James L. Seale, Jr., Charles B. Moss, and Carlton G. Davis (University of Florida)
The debt incurred by developing countries in the 1970s followed by increased real interest rates in the 1980s led to financial difficulties in these countries in the mid- and late 1980s. This study investigates the effect of financial stress on trade flows for several Caribbean and South American countries.

"LDC Debt and Policy Linkages in the Determination of World Commodity Prices." Gordon C. Rausser and Coleman D. Bazelon (University of California, Berkeley)
The effects of industrial country commodity policies and macroeconomic policies and the LDC external debt on world commodity prices are investigated. A theoretical framework is developed to provide the foundation for an empirical model that is estimated, assessed, and then simulated to isolate the effect of debt relief on commodity prices.

"Ghana: A Case Study in Macroeconomic Adjustment." William A. Amponsah and Leroy J. Hushak (Ohio State University)
Ghana's macroeconomic misalignment in the 1970s and 1980s necessitated structural adjustment. Using a multisectoral partial equilibrium model, we identify price incentives in the major export sectors, real exchange rate realignment, increased foreign capital inflows, higher interest rates, lower inflation, and domestic savings as major areas for government policy consideration.

Trade Liberalization Impacts (E. Kwon Choi, Iowa State University, presiding)

"Liberalizing Agricultural Policies in China: Effects on World Markets." Praveen M. Dixit and Shwu-Eng Webb (ERS USDA)
A world net trade model is used to study the distortionary consequences of agricultural protection in the People's Republic of China. Results suggest that Chinese policies have depressed world agricultural prices considerably, especially for rice and pork. The study also shows that policy reform in China would benefit producers immensely.

"The Impacts of Liberalizing Japanese Pork Markets." Thomas I. Wahl, Dermot J. Hayes, and Stanley R. Johnson (Iowa State University)

The paper examines the probable impact on Japanese pork consumption and imports of Japanese acceptance of the U.S. tarrification proposal.

"Trade Agreements and U.S. Citrus Exports to Japan." Pattana A. Jierwiriyapant, Jonq-Ying Lee, and James L. Seale, Jr. (University of Florida)
The Rotterdam model was used to study the Japanese import demand for U.S. citrus. Results indicate that U.S. fresh grapefruit exports to Japan would have to compete against imports of bananas and pineapples for the Japanese import dollars, and that U.S. citrus juice exports would have to compete against the juices from Brazil and Israel.

"Agricultural Policy Adjustments in the Korean Rice Economy." Hiroshi Yamauchi (University of Hawaii, Honolulu) and Yong Dae Kwon (Chungnam University, Korea)
A political preference function is used to endogenize government actions in a simultaneous equation model that is tested for Korean rice policy. The effects of macroeconomic changes on rice pricing decisions through estimated political weights are validated to open the way for better understanding of policy adjustments in East Asia.

"Rates of Protection in the Japanese Beef Market." Hiroshi Mori (Senshu University, Japan), William D. Gorman (New Mexico State University), and Biing-Hwan Lin (University of Idaho)
Rates of protection are estimated around 80% by comparing wholesale and CIF prices of imported "chilled carcasses" and ordinary imported beef. When LIPC's net profit figures are used, the rate of protection is found to be even smaller. Our estimates are substantially lower than most other studies.

Domestic and International Agribusiness Policy (S. Andrew Starbird, Santa Clara University, presiding)

"Agricultural Protectionism in a Strategic Trade Policy Context: An Application to the U.S. Cheese Market." Steve McCorriston (University of Exeter, Devon, England) and Ian M. Sheldon (Ohio State University)
Using a general conjectural variations model, this paper shows that even though import tariffs may be justified where markets are imperfectly competitive, such a policy may be inferior to alternative forms of trade intervention. These results are evaluated in the context of the U.S. cheese-processing sector.

"An Examination of the Likely Impact of the Withdrawal of Bovine Growth Promotants on the U.S. Beef Industry." Eric Grundmeier and Dermot Hayes (Iowa State University)
The paper examines the probable impacts on prices, quantities, and profits in the U.S. beef industry in the event of a voluntary ban on hormone use by beef producers.

"Off Farm Employment in Agribusiness: A Policy Perspective For Child Care and Family Support Programs." Forrest Stegelin (University of Kentucky) and Dolores Stegelin (University of Cincinnati)
A research-based policy position documents the expanding and critical role of corporate agribusiness in the provision of family-support and child care options for off-farm employed individuals and their families, especially as family-life issues top federal and states levels' legislative agendas.

"Opportunities and Pitfalls of International Futures Markets Trading by Developing Countries: The Case of Zaire Coffee Exports." Jack E. Houston and Mavuangi Khonde (University of Georgia)
Profitable direct and cross-hedging opportunities exist for Zaire coffee hedgers, and some periods may offer significantly superior opportunities. External events and internal policy changes contributed to instability of Zaire hedge ratios. The importance of internal economic and financial changes must also be considered to supplement international coffee market information.

"Multiproduct Costs, Shadow and Scale Elasticities: New Evidence for Fluid Milk Processing in the United States." Desmond F. Nolan (Pepsico), Cameron S. Thraen and David E. Hahn (Ohio State University)
The cost structure of the fluid milk-processing industry continues to change rapidly. Little is currently known about the internal cost/output structure of this important value-added food industry. This study provides new estimates of factor substitution and demand elasticities along with measures of cost and production scale elasticities.

Evaluation of Commodity Programs (Harry S. Baumes, Jr., ERS USDA, presiding)

"The Market Effects of Alternate Wool Policies." Glen D. Whipple, Dale J. Menkhaus, and John P. Hewlett (University of Wyoming)
The results of an analysis of the impacts of two policy alternatives to the wool act: An additional import tariff and restrictive import quotas are reported. They show that either approach could eliminate government expenditures while increasing producers' revenue. However, both place the burden for support on domestic wool consumers.

"The Impact of Product Demand and Government Intervention on Milk Prices." Kenneth W. Bailey, Abner Womack, and D. Scott Brown (University of Missouri)
This paper develops a framework to assess the impact of government intervention on the U.S. dairy industry. The model consists of markets for raw milk and three dairy products. The empirical results suggest that government removals have different effects on milk prices depending on which product is removed.

"Analysis of the Past and Future Impacts of the Wheat, Feed Grains, and Conservation Reserve Provisions of the Food Security Act of 1985 on U.S. Agriculture." John N. Ferris (Michigan State University)
AGMOD, an econometric model of U.S. agriculture, projected that the crop provisions of the Food Security Act of 1985 if continued at 1990 levels would contribute $7.5 billion in real (1982–84 $) discounted net cash income annually during 1986–2000, $3 billion of which is attributed to the Conservation Reserve.

"Production Rights with Limited Transferability: A Case Study of the U.S. Tobacco and Peanut Programs." Randal R. Rucker and Walter N. Thurman (North Carolina State University), Daniel A. Sumner (USDA and North Carolina State University)
Sale of tobacco and of peanuts into the domestic edible market requires quota. Recently, quota has been transferable only within counties. Such restrictions can cause deadweight costs. Our modeling and analysis of North Carolina data indicates that for peanuts these costs are zero and for tobacco they are relatively small.

"Spatial Distribution of the U.S. Dairy Industry: Long-Term Impacts of Policy Change." Jork Sellschop and Robert J. Kalter (Cornell University)
Use of a QP spatial equilibrium sector model showed that increased price supports shift dairy production westward. Reduced supports shift production northeast. Removal of fluid differentials without changing supports increases midwestern and Pacific but reduces northeastern and southeastern shares. Eliminating both policies boosts Lake States' share, reducing Northeast's and Southwest's.

International Policy Reform Considerations (Douglas Young, Washington State University, presiding)

"Lessons from New Zealand for Agricultural Policy Reform." William D. Dobson (Purdue University)
New Zealand's Labor government adopted sweeping agricultural policy and other economic reforms beginning in mid-1984. Farmers and agribusinesses generally adjusted effectively to the reforms. This paper discusses why and how the reforms were implemented and lessons others might extract from New Zealand's experience.

"Food Insecurity and the Role of Food Aid." Stacey Rosen and Shahla Shapouri (ERS USDA)
Food security can be defined as the ability of food deficit countries to meet target consumption levels. This paper evaluates the size and causes of food insecurity in thirty-five developing countries, assesses subsequent food aid response, and evaluates possibilities for increasing the role of food aid to improve food security.

"Dynamic Games in International Agricultural Policy." Shelley L. Thompson (University of Saskatchewan)
The formulation of agricultural policy in the U.S. and the EC is treated as a noncooperative dynamic game between governments and producers. The outcome of such policy is contrasted to cooperative policy. The results are discussed in the context of multilateral trade negotiations.

"A Model of Farm Behavior for the Current Chinese Grain Production Economy." Shihua Pan and Stanley R. Johnson (Iowa State University)
In the mixed system of China, marginal decisions of farms are affected by state prices only if market price is uncertain. If market price is known, marginal decision rules in market economics are directly applicable. Results under uncertainty show the importance of not simply ignoring free market price variability.

"The Impact of a Change in the Western Canadian Grain Transportation Policy." D. M. Dunlop and M. L. Lerohl (University of Alberta)
Current grain transportation policy subsidizes shipping export grain. This paper reports a simulation in which farmers pay full grain transport costs. Simulated over the 1983–87 period, the results suggest: (*a*) less grain production, mostly reduced barley output; (*b*) overall positive net welfare changes; and (*c*) reductions in shipping costs.

The Political Economy of Agricultural Policy (David Bullock, University of Illinois, presiding)

"Commodity Policy and Underinvestment in Agricultural Research." Harry de Gorter (Cornell University), David Nielson and Gordon C. Rausser (University of California, Berkeley)
Interactions between subsidies and the results of research efforts can lead to underinvestment in re-

search. Under conditions common to agriculture, subsidies can be used to compensate farmers for losses incurred from technical change. In such cases, underinvestment in research may be even more severe in the absence of subsidies.

"Accounting for Farm Programs." Julian M. Alston and Colin A. Carter (University of California, Davis), James A. Chalfant (University of California, Berkeley), and Steve Schonberger (University of California, Davis)
This paper synthesizes and extends the literature on political economy models of farm commodity programs. We examine thirteen agricultural products in a range of developed and developing countries. Our empirical results show that choices of policy instruments and levels of protection are jointly endogenous, depending on market and commodity characteristics.

"Budget Pressure and Farm Programs." Neilson C. Conklin (University of Arizona)
Institutional changes in the budget process have increased pressure on farm price support programs. The political-economic model in this paper suggests that budget pressure may bias policy toward supply controls.

"Optimal Evaluation of Research Portfolios." James F. Oehmke (Michigan State University)
This paper examines the optimal allocation of a given budget between research projects and the evaluation of these projects. Optimal evaluation expenditures increase as the budget increases and as the efficiency of evaluation increases relative to that of research. Results are interpreted in today's fiscal climate.

"An Evaluation of the Jamaican Agro 21 Export Diversification Program: A Policy Analysis Matrix Application." Carlyle A. J. Farrell (University of Manitoba)
The Monke-Pearson Policy Analysis Matrix is used to evaluate the economic impact of an export diversification program in Jamaica. Government policies failed to provide adequate protection to the program's winter vegetable sector; and resulting losses were J $100m. Gains from removal of inefficient policies are, however, too low to compensate for financial losses.

Alternative Production Practices in Agriculture (Roger Conway, ERS USDA, presiding)

"Agrichemical Restriction: Effects of Policy on Income and Its Distribution." C. Matt Rendleman (ERS USDA)
This study uses a ten-sector CGE model to measure the impact of a restriction in farm chemical use. Whether farmers benefit or not depends on whether a tax, a use restriction, or a production restriction is employed. In all cases, gross farm income rises but net income may fall.

"Commodity Programs and the Internalization of Erosion Costs: Do They Affect Crop Rotation Decisions?" Gregory L. Poe and Richard M. Klemme (University of Wisconsin), Shawn J. McComb (W.E.F.A. Group)
Using stochastic dominance, this paper investigates the impact of commodity programs and internationalization of erosion costs on crop rotation decisions. Commodity programs are found to shift decisions toward more erosive rotations. Internalization of erosion costs affect rotation decisions under historical market conditions but not under conditions of commodity program participation.

"Farm Program Impacts on Incentives for Green Manure Rotations." Douglas L. Young and Kathleen M. Painter (Washington State University)
Annual acreage reductions and deficiency payments generated mixed impacts on the relative profitability of a low-input versus conventional wheat rotation. Long-run incentives to maintain wheat base, however, introduced a consistent bias against the low-input green manure rotation. Current base flexibility proposals could reduce the "base barrier" to low-input rotations.

"Welfare Implications of Regulatory Policies Concerning Pesticide Residues in Food." Walter Ferguson (ERS USDA)
This paper illustrates the short-term implications for growers and consumers of the Environmental Protection Agency's new registration standard for lowering the risk from pesticide residues in food. National estimates are provided of the economic impacts of a fungicide ban on growers and consumers of nine vegetables and melon crops.

"Farm Policy Options for Agri-Chemical Reduction: A National/Regional Analysis." Kazim Konyar and Ian McCormick (ERS USDA)
Two scenarios that are designed to reduce nitrogen use are compared. The scenario that allows farm program participants to plant alternative crops on their base acreage results in lower government expenditures, lower farm income loss, and higher environmental benefits compared to the scenario that imposes a uniform tax on nitrogen use.

U.S. Trade Policy (Thomas Tice, AUS Consultants, presiding)

"U.S. Agricultural Policy and Environmental Quality: An Illustrative General Equilibrium

Model." James Tobey (ERS USDA) and Kenneth A. Reinert (U.S. International Trade Commission)
A simple general equilibrium model of international trade is developed to explore the resource use, income distribution, and environmental quality interactions of commodity and environmental policy toward agriculture. To analyze the environmental quality effects of policy changes, an environmental damage function is explicitly specified.

"An Agency Model of Expert Intervention: The Case of U.S. Wheat." David W. Skully (ERS USDA)
Public export agency intervention decisions are modeled in a principal-agent framework as balancing agency utility against budgetary costs. The CCC is shown to practice subsidy discrimination through its wheat export programs. The observed incidence of discrimination is consistent with the agency model. Implications for empirical demand estimation and wheat market modeling are discussed.

"Export Enhancement, Exporting Firms, and Efficiency of International Commodity Markets." Nicole S. Ballenger (Resources for the Future)
The large grain-export firms lobby against a U.S. export subsidy program that has paid nearly $3 billion in bonuses. This paper discusses the program characteristics that limit arbitrage opportunities and hinder traders' assessment and management of risk. These firm-level effects have implications for the international marketing system.

"Marketing Loan Programs and the Competitiveness of U.S. Cotton Exports." Carol E. Bray and Charles Bausell (U.S. General Accounting Office)
The U.S. cotton marketing loan did not keep U.S. cotton competitive on world markets in 1987 and 1988. Price relationships on the domestic market demonstrate that the U.S. loan rate continued to influence domestic floor prices, even under the marketing loan, through producer price expectations.

"U.S. Farmer Preferences for Agricultural Trade Policies: A Probit Analysis." Dennis A. Shields and Marshall A. Martin (Purdue University)
A probit model is used to estimate the influence of U.S. farmer characteristics on trade policy preferences. Four policies are considered: trade barrier reductions, farm subsidy reductions, world-wide production controls, and continuation of the Export Enhancement Program. Education, farm organization membership, and gross sales strongly influence farmer trade policy preferences.

Risk and Agricultural Labor (Joyce Allen, Joint Center for Public Studies, presiding)

"The Impact of Wage Differentials on Choosing to Work in Agriculture: Implications for the Immigration Control and Reform Act." Jeffrey M. Perloff (University of California, Berkeley)
A sample selection model of industry choice and wage determination was estimated for relatively uneducated rural males. A 1% increase in the relative wage in agriculture raises the probability of working in agriculture by 3.37% at the sample mean and by 1.3% averaged over the sample.

"The Impact of Nonfarm Labor Markets on Off-farm Income." H. Frederick Gale, Jr. (ERS USDA)
A regression model shows that higher nonfarm wage rates and lower unemployment are associated with greater off-farm income per farm. Effects are strongest in eastern regions and weakest in western areas. Off-farm labor supply appears quite responsive to nonfarm wages.

"The Saskatchewan All-Risk Crop Insurance Program: An Examination of Regional Insurance Value." W. P. Weisensel, W. H. Furtan, and A. Schmitz (University of Saskatchewan)
Saskatchewan Crop Insurance is an important stabilization program. However, critics maintain that it is not as useful to producers who farm in higher yielding regions. The purpose of this paper is to test the validity of these criticisms by comparing the regional value of insurance for various areas. The results support these criticisms.

"Explaining Participation in Federal Crop Insurance." Barry J. Barnett, Jerry R. Skees, and James D. Hourigan (University of Kentucky)
This study models participation in crop insurance for counties in thirteen wheat-producing states. The results indicate low price elasticity of demand for crop insurance. This suggests that a reduction in the loss ratio for crop insurance would be possible with an increase in rates.

"Effects of Disaster Assistance on Multiple Peril Crop Insurance Purchases by Iowa Crop Farmers." Mark A. Edelman (Iowa State University), Brian H. Schmiesing (South Dakota State University), and Khosrow Khojasteh (Iowa State University)
Logit regression was used to explain 1989 Multiple Peril Crop Insurance (MPCI) purchase decisions by Iowa Crop Farmers. The primary explanatory factor was whether MPCI had been purchased in 1988. Disaster payments and expectations that government would pass future disaster legislation were also found to reduce MPCI purchases.

Agriculture, Policy and Stabilization (Zuhair Hassan, Agriculture Canada, presiding)

"Estimating Price Distortions Caused by Canadian Wheat Board Initial Payment Policy." J. Stephen Clark and Catherine Fleming (University of Saskatchewan)
Limited dependent variable regression techniques are used to measure price distortions caused by initial payments as price floors. The results indicate that the degree of uncertainty producers have regarding the price floor is the critical issue in the level of price distortions.

"Impact of Changes in U.S. Grain Standards on Discounts for Insects in Stored Grain." Ronald Fleming, Bryan Schurle, Steven Duncan, and Carl Reed (Kansas State University)
The Federal Grain Inspection Service changed U.S. grain standards in 1988. Insect discounts given at the country elevator and at the terminal elevator level were analyzed for the impacts of the new standards. Insect discounts influence grain quality by affecting insect control decisions by farmers and elevator managers.

"Announcement and Implementation Effects of Agricultural Policies: An Example of Trade Liberalization." George C. Davis (North Carolina State University)
This paper demonstrates the policy announcement and implementation effects of direct intervention in agricultural markets. The importance of assuming inventories either depend only on predetermined variables or are constant in policy analysis is shown.

"Measuring Agriculture's Total Contribution to the Economy: A Sequential Extraction Approach." Carol A. Ferguson, John M. Halloran, and Stuart T. Nakamoto (University of Hawaii-Manoa)
Measurement of agriculture's economic contribution must consider possible replacement of farm production by imports and induced loss of forward-linked sectors. Sequential extraction, an input-output technique, is applied to the food system to assess total economic activity attributable to agriculture. The approach is demonstrated using Hawaii state data.

"Efficiency of Price Stabilization Under Rational Expectations." Robert Matheson and J. Stephen Clark (University of Saskatchewan)
The "price efficiency" of price stabilization programs is a function of the speed of convergence and path of prices. By examining the roots of a system of prices this efficiency level can be compared under alternative stabilization schemes. This recognizes the policy invariance of parameters under the rational expectations hypothesis.

Consumer and Household Economics (Jeff Alwang, Virginia Polytechnic Institute and State University, presiding)

"Product Quality and Value for Processed Foods." Orlen Grunewald (Kansas State University) and David J. Faulds (University of Tennessee)
This study investigates quality and value comparisons between national and private label brands of processed food products. Regression analyses indicate a weak relationship between price and quality for such products. Private label and national brands offer similar product quality, while private labels offer better values for consumers.

"The Effect of Functional Form on the Estimated Marginal Propensities to Spend Out of Food Stamps and Money Income." J. William Levedahl (ERS USDA)
With linear in the coefficients specifications, the marginal propensity to spend (MPS) on food out of food stamps is four–six times the MPS out of income. Using a generalization of Roy's identity and flexible indirect utility functions, alternatives were estimated.

"Income Sources of the Rural Poor: The Case of the Zona da Mata, Minas Gerais, Brazil." Stephen A. Vosti and Julie Witcover (International Food Policy Research Institute)
Microlevel data from Brazil show that higher household income is neither necessary nor sufficient for improved nutritional status. Income sources and output mix, which affect household access to food and intermediate health inputs, are linked to nutritional status. Female-headed households stand out, parlaying low income into high caloric intake; off-farm agricultural labor income was tied to lowered caloric intake.

"The Demand for Fresh Fruit: Nonparametric and Parametric Analysis." Gabriele Dono, Gary D. Thompson, and Nielson C. Conklin (University of Arizona)
During the last two decades, per capita consumption of fresh fruit has increased markedly. Although conventional wisdom suggests that this increase may be caused by heightened consumer concerns about health and diet, nonparametric tests can detect no change in average consumer preferences. Elasticity estimates indicate that grapes and strawberries have increasingly substituted for citrus fruit, particularly grapefruit.

"The Supply of Off-Farm Labor: A Random Coefficients Approach." Daniel A. Lass (University of Massachusetts) and Conrado M. Gempesaw, II (University of Delaware)

Off-farm labor supply functions are estimated by random coefficients techniques. Results are compared to standard selectivity results and variation in parameters considered. The random coefficients model appears to work well as an alternative to selectivity models and provides useful information on variation in individual responses to exogenous factors.

Regional Economic Analysis (Kevin McNamara, Purdue University, presiding)

"Economic Impacts of the Conservation Reserve Program in Virginia: A Break-even Analysis Using the IMPLAN Input-Output Model." Paul B. Siegel and Thomas G. Johnson (Virginia Polytechnic Institute and State University)
This paper assesses economic impacts of expanded enrollment in the Conservation Reserve Program in Virginia. It calculates break-even economic levels from the perspective of farmers and the regional economy and refines the appropriate interpretation of total gross output, employment, and income impacts in applications of input-output analysis to set-aside programs.

"Regional Impacts of the Conservation Reserve Program in the Southeast with Conversion to Trees: An Application of Input-Output Analysis." David E. Broomhall and Thomas G. Johnson (Virginia Polytechnic Institute and State University)
Using input-output analysis, this research shows that local economic impacts of the Conservation Reserve Program may be substantial in areas where land conversion is primarily to trees. Economic output and employment are estimated to decline in the early stages but later increase substantially during the tree harvest.

"Rural Economic Development in Multiregional Environment." David S. Kraybill (University of Georgia)
A multiregional computable general equilibrium model is used to analyze alternative rural economic development policies. Labor and capital subsidies are examined to determine their effectiveness in the presence of regionally exogenous shocks originating at the national and international levels.

"Estimating Regional Exports and Imports in U.S. Rural Development Models: Toward an Understanding of Spread and Backwash Effects." Binayak Bhadra (Tribhuwan University, Kathmandu, Nepal) and Bruce Weber (Oregon State University)
Testing rural-urban spread and backwash mechanisms require substate estimates of gross exports and imports. "Regional-purchase-coefficient"-based methods for estimating county-level gross trade flows are evaluated. Some obstacles to validation are identified. Multiregional rural-urban models are needed to better understand rural-urban interdependencies and development dynamics.

"Input-Output and Alternative Regional Models for Welfare Analysis." Roger Mann (Hydrosphere, Inc.) and Robert A. Young (Colorado State University)
Input-output is often used for analysis of regional welfare although the method must be augmented with additional information to obtain welfare implications. An interindustry linear programming model and a model using price responsive factor demands are used to evaluate a proposed irrigation development in southwestern Colorado.

Rural Development: Retail, Value-Added, and Diversification Opportunities (Larry Sanders, Oklahoma State University, presiding)

"The Measurement of a Community's Retail Market." James C. McConnon, Jr., and Steven C. Deller (University of Maine), Kenneth E. Stone (Iowa State University)
This paper provides a direct comparison of retail market population computed by the Reilly's Law method and the trade area analysis method. The results suggest that, over the entire sample, the two measures of market population are statistically equivalent. However, Reilly's method computed a larger market population for smaller communities.

"Implications of Alternative Farm Policy Regimes on Community Retail Sales." David A. Henderson (ARED ERS USDA)
A model using data from the Corn Belt indicates the elasticity of retail sales with respect to crop sales, livestock sales, and government payments varies by type of retail business and size of community. The results are useful for evaluating the effect of alternative farm policies on rural retail sales.

"Value Added versus Value Leaked: High Value Agricultural Exports from a State Perspective." Stuart T. Nakamoto, Carol A. Ferguson, and John M. Halloran (University of Hawaii at Manoa)
Input-output models can provide valuable assistance in identifying sectors which have large positive impacts on the economy. In agriculture, the tendency to promote sectors with large processing components may be misguided. A more sound criterion is to look at the portion of value-added which is retained in the local economy.

"Measures and Determinants of Agricultural Diversification." Mary E. Young (University of Texas at Dallas)

Efforts to revitalize rural economies through agriculture-related diversification have increased in popularity. Six measures of regional agricultural diversification were calculated, and a model of the determinants of regional diversification was tested. The results suggest that diversification is significantly related to farm size, irrigation, other income sources, and location.

"How Diversified Is Your State's Agriculture?" Loren W. Tauer (Cornell University)
Each state's agricultural production diversification is measured for 1984 and 1988. Very little difference existed between the type of index used or the year computed. Linear regressions of the coefficient of variation of receipts on diversification measures imply diversification among states has no impact on variability of receipts.

Local Government and Finance (Tom Harris, University of Nevada, Reno, presiding)

"Size Economics versus Managerial Efficiency in Local Government: Do We Know What We Are Measuring? Edward Rudnicki and Steven C. Deller (University of Maine)
Allowing for managerial inefficiency in public education, the hypothesis of size economies is examined. While size economies are identified in the traditional model, no size economies are identified under the more general model of managerial inefficiency. These results suggest that previous studies may incorrectly attribute managerial inefficiencies to size economies.

"The Political Economy of Highway Appropriations for Rural Development." Teresa D. Taylor (TVA Agricultural Institute) and Josef M. Broder (University of Georgia)
This paper examines the allocation of public funds for highway construction. A public choice framework was developed to identify factors associated with highway construction in Georgia. Highway appropriations were found to be associated with economic, demographic, and physical characteristics of the locality and the distribution of political rewards to decision makers.

"The Distributed Lag between Transportation Expenditures and Rural Income and Employment." Laurence M. Crane and David J. Leatham (Texas A&M University)
Effects of Texas transportation expenditures on income and employment were evaluated using distributed lags. A 1% increase in transportation expenditures in rural counties increased farm income 1.93% distributed over four years, nonfarm income 0.86% over six years, farm employment 0.29% over five years, and nonfarm employment 0.37% over nine years.

"Improved Measures of Manufacturing Attraction: The Role of Industrial Site Hedonic Prices." Warren Kriesel (University of Georgia) and Kevin T. McNamara (Purdue University)
An estimated industrial site price is included in a manufacturing location model to examine the impact that site quality has on firms' location decisions. The model is estimated with an ordered, categorical logit model. The results suggest that site quality and other location attributes are important location determinants.

"Changes in Commercial Bank Lending for Agriculture and Real Estate Associated with Banking Regulation." George K. Townsley (Farmers Home Administration) and Mark D. Lange (Louisiana State University)
Changes in portfolios of banks in the U.S. southeastern bank market associated with changes in federal and state regulations are analyzed. Percent of total assets held in real estate and agricultural loans decrease and liquid asset positions increase as banking laws become less restrictive. Acquired banks respond similarly in asset adjustments.

New Directions in Extension Programming (Darrell Peel, Oklahoma State University, presiding)

"A Comparison of Risk Performance Measurements with Implications for Extension Programming." Bryan W. Schurle and William I. Tierney, Jr. (Kansas State University)
Three measurers of risk preference were collected from ninety farmers along with additional information about their farm operations. Two of these instruments were correlated while the third was not. Risk preferences appear to be related to characteristics of the operation which has implications for marketing and farm management extension programs.

"Obstacles to Communication in Water Policy Education." Amy Purvis, R. Jeffrey Burkhardt, and Roy R. Carriker (University of Florida)
Water policy education can be instrumental in defining a proactive role for individuals who are concerned about the changing interface between environmental quality and farming. Obstacles to communication occur because people have different viewpoints concerning environmental quality. Some insights are outlined concerning how to design effective water policy education initiatives.

"Both Urban and Rural Interests Have a Stake in the 'Farm' Bill: A Report on Roundtable Discus-

sions of the 1990 Agricultural Legislation." Laurian Unnevehr (University of Illinois)
The increasing role of nonfarm groups in the agricultural policy process creates an opportunity for public policy educators. Roundtable discussions of the 1990 agricultural legislation in Illinois brought together citizens from farm and urban backgrounds to exchange ideas. These meetings met a desire for communication between traditional farmers and environmentalists.

"Extension Microcomputer Education in Farm and Ranch Management in Texas." James M. McGrann and Donald Breazeale (Texas A&M University)
The potential of the microcomputer to become an important management tool was recognized early by the Farm and Ranch Management Extension faculty at Texas A&M University. The paper presents an evaluation of the intensive training courses, software development, and distribution effort. Participant demographic characteristics and evaluations provide information on the target audience and program effectiveness.

"An Evaluation of the Use of Enterprise Budget Information by County Agents." DeeVon Bailey and Douglas W. Eck (Utah State University)
A regression analysis was performed to determine the factors influencing the number of times county agents directly referred to published enterprise budget information in a year. The agent's understanding of the use of budget information in management decisions, the geographic units that budgets were published for, and receiving the budgets in multiple forms had significant positive impacts on the use of budgets by the agent.

Evolving Educational Responses (Ralph Christy, Louisiana State University, presiding)

"Student Perceptions of Cognitive Skill Achievement in Agribusiness Management." Dennis M. Conley (University of Nebraska)
Educators recognize the need to integrate higher-order cognitive skills into courses but have difficulty in trying new methods. Active participation in an agribusiness management game is tested, with lecture dominated class time reduced, to evaluate the effect on student use of cognitive skills.

"Innovating Teaching of a Commodity Price Risk Management Course for Agribusiness Students." Larry Martin and Francesco S. Braga (University of Guelph)
State-of-the-art communication technology was used to teach a senior course on risk management. The paper describes how to integrate classroom lecture with preparation of market reports, using both Reuters and other hard copy material. Student participation was an important part of this course.

"Dealing with Drought: A Review of Our Professions' Response and Ideas for Improving It." William I. Tierney and David L. Darling (Kansas State University)
The recent droughts were a challenge to our discipline. This paper examines how agricultural economists in Kansas and other midwestern states responded to producers' and public policy makers' need for timely information. It concludes with ideas for designing drought programs in the future.

"Determinants of Agricultural Economics Faculty Retirement." Josef M. Broder and Fred C. White (University of Georgia), Teresa D. Taylor (TVA Agr. Institute)
Relationships among faculty characteristics and retirement age were examined. Years of service to retirement programs, number of children, mental health, health trends, age at initial employment, faculty-spouse age differences were positively related to retirement age. Salaries, net worth, and extension appointments were inversely related to retirement age.

"Nebraska Integrated Resource Management Demonstration Herd Project." W. Marshall Frasier, George H. Pfeiffer, Richard J. Rasby, Gene H. Deutscher, and Don H. Hudson (University of Nebraska)
Cooperator herds were employed to demonstrate improved profitability in cow/calf operations in Nebraska as the result of alternative management practices implemented. An interdisciplinary team of specialists developed recommendations for each operation. Biological and financial data were collected and analyzed on each operation and used in various educational activities.

Posters

"Long-Run Supply, Technology Restrictions, and Selected Environmental Impact." Burton C. English (University of Tennessee), Thyrele Robertson (SCS USDA), and W. Robert Goodman (University of Tennessee)
Policies targeting production technologies will impact environmental issues, international trade concerns, and agricultural land-use patterns. This research describes relationships between the price and supply of commodities, erosion levels, and U.S. planted cropland acreage as elements of sustainable agriculture technology are incrementally assumed using the ARIMS linear programming model.

"The Effects of Capital Gains Tax Reduction on U.S. Natural Resources: Agriculture, Forestry, and Resource Conservation." Liu-Hsiung Chuang (SCS USDA), Ronald Durst (ERS USDA), Karen Liu (Forest Service, USDA)
This study examines the effects and implications on agriculture, forestry, and resource conservation of the president's proposed reduction in capital gains taxation. First, the president's proposal is contrasted with the capital gains tax provisions in place before and after the 1986 Tax Reform Act. A review of the major elements of the president's proposal and their economy-wide effects will follow, with particular emphasis on the relative effects on agriculture, forestry and resource conservation. Finally, specific effects of the president's proposal on agriculture, soil and water conservation, and forestry will be detailed.

"Cost Effectiveness of Water Quality BMPs in the Chesapeake Bay Program." Donald J. Epp and James M. Hamlett (Pennsylvania State University)
The CREAMS model is used to compare sediment and nutrient losses of three fields under seven different BMPs. Changes in the present value of field net income and societal costs are calculated and combined with CREAMS results to produce cost-effectiveness measures of each BMP.

"Wither Irrigation?" William Quinby and John Hostetler (ERS USDA)
Analysts who rely on recent trends in the Census of Agriculture to predict future acreage of irrigated land in farms will be in for a surprise. The 1987 irrigated area was low because short-term cropland diversions were high. The background trend remains positive. This is confirmed by census trends for irrigation dependence.

"Development of the Micro-Oriented Sediment Simulator II." Robert R. Alexander and Burton C. English (University of Tennessee)
MOSS is intended as an aid to soil erosion researchers and policy makers in assessing the offsite costs of various erosion scenarios. Primarily a national-level tool, MOSS estimates sediment entering waterways and tracks the movement of the sediment downstream. Sediment damage costs are calculated based upon distribution of the sediment.

"Decision Aids in Conservation." Gail E. Updegraff, John H. Stierna, Douglas A. Christensen, and Douglas J. Lawrence (SCS USDA)
The Soil Conservation Service (SCS) has developed a decision-making framework that requires site-specific quantitative monetary and nonmonetary information. The purposes of this poster paper are to disseminate information about the SCS decision-making process, obtain information about existing farm-level decision aids, and demonstrate the SCS crop budget generator program.

"Willingness to Pay, Perceptions of Right, and Illegal Salmon Fishing: An Assessment of Quebec's Recreational Salmon Fishing Policy." James R. Wilson and Roxane Bouchard (Université du Québec à Rimouski)
Average willingness-to-pay measures from a binary contingent valuation survey question were developed for different income groups and for different rivers in the province of Quebec. Preliminary results suggest that the disparity in both income and rights perceptions within the sample militate heavily against the successful achievement of a comprehensive "pay by the day" policy of river access rights throughout Quebec.

"Sampling CRP Contract Holders on Future Land Use." Robert W. Lenkner and M. J. Monson (University of Missouri)
The Conservation Reserve Program (CRP) removed significant acreage from production in Missouri. Anticipating the actions of producers upon expiration of CRP contracts requires information on the economic and demographic factors which influence their decisions. A survey and stratified sample of contract holders is utilized to elicit this information.

"Returns to Education in Rural Areas: Evidence of Weak Demand for Highly Educated Workers." Linda M. Ghelfi and David A. McGranahan (ERS USDA)
Rural areas exhibited weak demand for highly edu-

cated workers during the 1980s. Evidence of weak rural demand includes an increasing metropolitan share of jobs for the highly educated, smaller returns to education in rural areas, and outmigration of better educated rural workers to metro areas.

"Revitalizing Rural Florida: A Multi-Discipline Approach to Agricultural Economic Development." Timothy D. Hewitt and David Zimet (University of Florida)
As in many other areas an effort is underway in the Florida Panhandle to improve rural incomes and to diversify current agricultural activities. A multiagency approach was undertaken to attempt to attract agriculture related industries to the area as a way of strengthening the rural economy of north Florida.

"Economic Analysis of Selected Industries Dependent upon the Bridger-Teton National Forest." David T. Taylor, Robert R. Fletcher, and Jeanette M. Oster (University of Wyoming)
Input-Output analysis can serve as guide in evaluating the economic impact of structural change within a region's economy. In this study, the analysis is used to estimate the potential economic impact on selected Wyoming counties from the management alternatives proposed in the Bridger-Teton National Forest Plan.

"The Consequences of Fatal Farm Accidents in New York: Family Displacement and Foregone Income." Timothy W. Kelsey (New York Center for Agricultural Medicine and Health)
The effect on families of fatal accidents in farming, the nation's most dangerous occupation, is great. This study found 68% of victims' families in New York no longer operated their farms and 44% have moved. Average lifetime expected income lost was $338,795 per hired worker and $307,179 per operator.

"An Economic Analysis of the Social Costs of Brazilian Ethanol Production: 1977–87." Kevin Rask (Duke University)
Environmental concerns, foreign exchange crises, and high oil prices have led to increased world demand for alternative energy sources. A social cost benefit analysis of the Brazilian ethanol program is undertaken to evaluate the efficiency of production of this renewable resource. The results show significant net social costs to ethanol production in Brazil.

"NEMPIS: National Economic Milk Policy Impact Simulation." Harry M. Kaiser (Cornell University)
The purpose of this poster is to demonstrate a computer simulation program which simulates farm and retail market impacts of user-selected dairy policy and technology scenarios. The program, which is called National Economic Milk Policy Impact Simulator, is free to anyone supplying the author with a floppy diskette.

"The Packing Simulation Model." Constance L. Falk (New Mexico State University) and R. Joe Schatzer (Oklahoma State University)
The Packing Simulation Model is a microcomputer application program designed for researchers, extension personnel, bankers, packing managers, or other specialists who plan the operations of a packing facility or simulate its financial performance. PACKSIM produces pro forma financial statements for packing facilities based on flexible crop mixes and packing assumptions.

"An Application of Experimental Economics in Marketing Research." Dale J. Menkhaus, Glen D. Whipple, Ray A. Field (University of Wyoming) and Elizabeth Hoffman (University of Arizona)
Marketing research has focused primarily on assessing consumer appeal with little attention given to the important issue of value. In this study, experimental economics was used to determine the economic value consumers place on vacuum packaged retail beef. With information, the vacuum package enhances the value of beef.

"Reducing the Cost of Marketing Beef through Central Retail Fabrication and Packaging." D. E. Farris, J. B. Ward, R. A. Dietrich and D. W. Holloway (Texas A&M University)
Central fabrication and packaging of retail beef can reduce consumer beef prices as much as 10¢ per pound. A national beef fabrication and marketing model was developed to analyze the economics of seven alternative systems for producing retail beef for thirty regional U.S. markets. Estimates of comparative advantage in expanding fabrication and packaging plants were most favorable in the Southern and Central Plains.

"GMX: A Grain-Marketing Expert System." Larry Lev, James Cornelius, and John Bolte (Oregon State University)
The Grain-Marketing Expert (GMX) is a rule-based expert system that utilizes knowledge from grain marketing experts in conjunction with information provided by the producer to develop a personalized short-run marketing strategy. Field validation of the program has demonstrated that GMX is user-friendly and provides useful recommendations.

"Buyers' Power and Factors Influencing Pecan Farm Prices." J. C. Purcell, W. J. Florkowski, and E. E. Hubbard (University of Georgia)
Growers receive different prices for pecans because of quality differences determined by management

practices, genetic makeup of trees, and concentration of buyers. Results suggest that growers must eliminate inferior pecan varieties from orchards and may consider organizing cooperatives for the purpose of marketing pecans.

"Lead-Lag Price Relationship between Government and Private Retail Outlets in a Planned Economy." Wojciech J. Florkowski (University of Georgia)
Lead-lag price relationship was tested for vegetable prices on farmers' markets and government stores in Poland using monthly data from 1970 to 1986. Results suggest that farmers' market price adjusted faster to changing market conditions and could reflect the condition of the economy more accurately providing useful information to a central planner.

"Structure of Dairy Consumption in West Africa." Siegfried Debrah (International Livestock Centre for Africa)
Dairy consumption research has not received enough attention to Sub-Saharan Africa. The few studies that exist aggregate all dairy products as one commodity and do not differentiate among consumer categories. This study uses a disaggregated analysis and estimates income-group-specific demand parameters which are more useful in studying the consumption patterns of the various consumer categories as well as analyzing the implications of dairy self-sufficiency policy on families in different income strata.

"Evaluation of an Expert System for Apple Pest Management." A. Laughland, W. N. Musser, T. Bowser, E. G. Rajttte, C. E. Sachs, R. Crassweller, L. A. Hull, J. W. Travis, and K. Hickey (Pennsylvania State University)
Expert systems are a method for adapting management recommendations to specific production situations. This poster reports on a multidisciplinary evaluation of the release of an expert system to a pilot group of growers. Behavioral, social, technological, and economic aspects of the evaluation are reported along with implications for future distribution.

"Differences in Access to and Reliance on Public and Private Information Sources by Farm Size and Enterprise: Implications for Effective Information Transfer." Nona R. French (University of Georgia) and Jackie B. Langston (North Carolina Rural Economic Development Center)
Data from a survey of 700 North Carolina farmers is used to examine differences in successfully obtaining and reliance upon public and private sources for different types of information. Farmer characteristics will be employed in multinomial probit. Results will identify information gaps and effective information transfer modes for varying clientele.

"Measuring Teaching Quality in U.S. and Canadian Departments of Agricultural and Rural Economics." Josef M. Broder (University of Georgia), William J. Taylor and John B. Rowsell (Virginia Tech)
This poster presentation examines Student Evaluation of Teaching (SET) instruments and statistical summaries used by agricultural economics and related departments in the U.S. and Canada. Theoretically desirable attributes of SET instruments and statistics are identified. Effective SETs and statistical summaries currently being used are displayed and critiqued.

"Computer Analysis of Futures and Options Market Strategies." M. J. Monson and David Miller (University of Missouri)
Marketing strategies created through combinations of cash positions, futures and options contracts can result in complicated effective-price profiles. A computer program is developed as an aid to producers in visualizing the effective-price and effective-revenue profiles with complex futures and options position.

"Large-Scale, Cross-Commodity, Econometric, Trade and Policy Models: Can We Talk?" Hsin-Hui Hsu (ERS USDA CED Crops)
Large-scale commodity simulation models are limited in design for complicated operating and management concerns. An integrated interactive system of core models could expand analytical capability of individual models to achieve both better understanding and avoiding bias in the policy formulation. This poster presents five USDA ERS in-house models with an application of research design in examining the planting flexibility issue.

"Data: An Issue Whose Time is Now." Leroy J. Hushak (Ohio State University) on behalf of the AAEA Economic Statistics Committee
In late 1987, the Economic Statistics Committee of AAEA undertook to develop a major survey of data needs of rural social scientists and a symposium to address data issues. The survey and symposium were completed during 1989. The purpose of the poster is to report these efforts and to update AAEA members on current data initiatives.

"Concept Mapping in Teaching: A Tool for Integration and Communication." Deborah H. Streeter (Cornell University)
A technique called concept mapping can be used by teachers to emphasize meaningful (conceptual) learning over rote memorization. The maps presented illustrate the use of concept mapping to (*a*) integrate interdisciplinary ideas in a course in information systems and decision analysis and (*b*) identify conceptual problems in an independent study project.

"Economic Series Analyzer—A Computer Program for the Applied Analyst." Richard G. Heifner and Nicholas J. Powers (ERS USDA)
This completely menu driven software makes data analysis fun for students and analysts who desire a program with very low startup time. The program functions can be broadly categorized as (*a*) data manipulation, (*b*) graphics, (*c*) descriptive statistics and nonparametric tests, and (*d*) regression analysis.

"A Revolution in Data Use and Dissimination: Implications for Agricultural Economics." Alan Webb (ERS USDA ATAD), Karl Gudmunds (University of California, Davis) and Gene Hasha (ERS USDA CED)
Data manipulation has always been a cumbersome but necessary element in economic analysis and research. A new set of software programs built around major USDA data sets promises to facilitate initial data analysis. This poster will demonstrate the value of these developments to researchers, teachers, extension economists, and policy analysts and provide a basis for discussion of future developments.

"Motivation of Group versus Individual Behavior: An Educational Futures and Options Trading Club Application." Eluned Jones (Virginia Polytechnic Institute and State University), Russ Perkinson (Virginia Cooperative Extension Service), and Anthony Townsend (Virginia Polytechnic Institute and State University)
Group behavior, as manifested in an Educational Futures and Options Trading Club, indicated that group participation and decision making achieved greater success than individual programs. Financial involvement in concert with group and sub-group interaction influences the experiential learning aspect of the trading clubs.

"Prevailing Wage and Practice Surveys in Agriculture." Robert D. Emerson, Leo C. Polopolus, Sharon Moon, and Noy Chunkasut (University of Florida)
A research and training program for conducting prevailing wage and practice surveys in anticipation of foreign worker requests is displayed. A methodology is set forth for obtaining a representative sample of employers of seasonal agricultural labor. A significant training program component is the computerization of the questionnaire and interview process.

"Managing Main Street Business: A Proven Rural Revitalization Program." Larry B. Swain and Steven A. Schulz (University of Nebraska)
The "Managing Main Street Business" program has proven to be an effective new method of program delivery for the University of Nebraska Cooperative Extension. Workshop series are conducted in rural communities, particularly those designated as agriculture dependent. Contract instructors are used to deliver "custom fit" management programs to clientele throughout Nebraska.

"Developing Extension Education Programs on Macroeconomic Policy Linkages to Agriculture." William M. Snell, Orlando D. Chambers, and Craig L. Infanger (University of Kentucky)
This poster identified ways to implement/improve extension education programs on macroeconomic linkages to agriculture. Various advantages to the clientele, programming strategies, and support materials were presented. The poster display also contained flowcharts, graphical displays, and microcomputer screenshows to illustrate examples of monetary, fiscal, and trade policy linkages to agriculture.

"Microcomputers: A Tool for Distance Education." Joan R. Fulton (University of Minnesota)
A program utilizing microcomputers for homework assignments at a junior college in rural Saskatchewan is described. The benefits to the students, the college, and the instructor are identified.

"Learning About Corn Yield Response to Nitrogen Fertilizer When Rainfall Is Stochastic: A Simulation Model." Scott M. Swinton (University of Minnesota)
A microcomputer model simulates farmer learning about corn yield response to nitrogen fertilizer. The model uses a sequential regression algorithm to update estimates of the profit-maximizing fertilizer rate. Experiment leads to higher discounted net worth than passive or no learning strategies.

"Impact of the Federal Feed Grain Program on the Profitability of Alternative Cropping Systems." J. Randy Winter, Rick C. Whitacre (Illinois State University)
Replicated plots were utilized to examine the profitability of various rotations on highly productive Midwest farmland. Based solely on market returns, the rotations were more profitable than continuous corn. However, when the benefits of the 1985 Feed Grain Program were considered, corn production was most profitable. The results indicate that the benefits of the government program can influence farmers' crop production decisions.

"A Return-Risk Analysis Incorporating Capital Structure and Seasonability of Fresh Market Vegetables." J. W. Prevatt (University of Florida), L. L. Bauer, E. H. Kaiser, and P. J. Rathwell (Clemson University)
A Target MOTAD model was formulated to examine the return-risk relationships associated with capital structure and seasonality of fresh market vegetables. The impact of the target return level on enterprise

mix, risk magnitudes, the rate of change of risk magnitudes, and operating capital requirements were significantly different among seasons.

"Milk Yield Distribution within a Dairy Herd and Adjustment to BST Use." S. J. Monson, Timothy Bargary, and M. J. Monson (University of Missouri)
This research depicts a construct that recognizes the relationships between BST use and yield distribution within a herd. The distribution of milk yield within a herd proves to be a critical variable in determining the size of the dairy herd where a decrease in cow numbers will occur.

"Coordinated Programs: Farm/Ranch Management." John P. Hewlett and James J. Jacobs (University of Wyoming)
To efficiently utilize the limited resources of time and money, educational programs should be focused and an organizational structure established. These programs should be offered in a collaborative framework that recognizes the autonomy of all players, while giving each individual maximum flexibility in developing and providing his/her contributions.

"Assessing the Economics of Alternative Enterprises: A Case Study." Gayle L. Pounds, Larry W. Dorman, and Carole R. Engle (University of Arkansas at Pine Bluff)
The poster illustrates the process of analyzing the feasibility of an alternative enterprise, using baitfish production as an example. Capital investment requirements, annual cost and returns, cost decomposition, and cash flow budgets were estimated and analyzed for three farm sizes. Financial effects of fluctuations in selected parameters were estimated.

"Economics of Alfalfa Persistence and Replacement." Kevin C. Moore, Hans McDonald, John Coutts, Baryl Buchholz, and C. Jerry Nelson (University of Missouri)
A replacement decision model for continuous alfalfa production was developed. Emphasis was on stand life and phosphorous and potassium application. Optimal strategies for each plant nutrient simultaneously with stand life were determined. A stand age of eight years maximized annualized returns for both cases. Sensitivity analyses were performed and the solutions were found to be quite stable.

"The Preference Function of U.S. Wheat Policy during the Eighties." Arie Oskam (Wageninger Agricultural University) and Harald von Witzke (University of Minnesota)
A revealed preference approach was used to derive a policy preference function. Conscious decisions reveal the relation between the target variable of policy makers. The methodology was applied to U.S. wheat policy during the 1980s. Most consequences of decisions were calculated using WHEATSIM. The resulting preference function followed from a linear programming solution that minimizes calculated inconsistency of decision making.

"Farm-Level Impacts of Multilateral Trade Liberalization Case Studies of the U.S. and France." Christian Mainguy (ENITA-Dijon, France), C. Parr Rosson, III, Amy Angel (Texas A&M University), and Johnny Jordan (Clemson University)
A firm-level, recursive, simulation (FLIPSIMV) was used to estimate the financial impacts of multilateral trade literalization on selected case farms in the U.S. and France. Results indicate that all farms experience substantial decline in net cash farm income, loss of equity in the operation, and a decline in returns above variable costs. Declines in farm financial situation are most severe for the South Carolina farms and French farms. The Illinois farms were less adversely affected.

"Analysis of Grain Stocks Proposals for the 1990 Farm Bill." Frederick Nelson, Mike Price, Jerry Sharples, Paul Westcott, Robert Reinsel, and Harry Baumes (ERS USDA)
Proposed changes in U.S. stocks programs will contribute to an overall objective of moving towards market orientation in grain markets. Costs of the stocks programs may be reduced, but there will be less protection from price variability than with the old FOR. Producers will receive fewer benefits.

"Forecasting Wheat, Corn, and Soybean U.S. Exports with Fixed and Stochastic Coefficients Estimators." Roger Conway, Nathan Childs, Kevin Ingram, and Carlos Arnade (ERS USDA)
Do time-varying parameter models help provide useful export forecasts by incorporating volatility inducing factors into estimation? We compare various time-varying parameter models with fixed coefficients competitors and estimate soybean, corn, and wheat export equations for each model. Fixed coefficients models are found to be generally superior.

"EC Sugar Market Confronts GATT and EG 1992." Dale Leuck, Steven Neff, and Liana Neff (ERS USDA)
Trade negotiations in the General Agreement on Tariffs and Trade (GATT) imply possible elimination of the European Community (EC) sugar program, while an EC-wide reform initiative implies possible reallocation of EC production. Both initiatives reduce trade distortion by similar magnitudes, but each has different implications for the EC and countries having preferential sugar export arrangements with the EC.

"How Level Is the Playing Field?" Carl C. Mabbs-Zeno and Renata Penn (ERS USDA)
This poster presents producer subsidy equivalent for

twenty-eight countries showing how much support their producers receive as a result of government policies. Support varies among commodities within the United States as a result of both domestic pressures and the distribution of support among commodities by our competitors.

"Weather and Soviet Agriculture: Implications of an Economic Model." Robert L. Kellogg (ERS USDA) and Barbara Severin (Central Intelligence Agency)
Soviet agriculture is modeled as a function of capital, labor, weather, and government policy. The model is used to disentangle the effects of weather from the impact of government policies. Analysis indicates it will be difficult to domestically produce enough food to meet demand in the 1990s. Additional imports are likely.

"What Is an Agricultural Subsidy? The Case of Canadian Hogs and U.S. Corn and a Comparison with the FTA and the U.S. and Canadian GATT Proposals." Carol Goodloe (ERS USDA)
The decisions reached in the U.S. countervailing duty case against Canadian hogs and in the Canadian case against U.S. corn are compared to highlight similarities and differences in the criteria used to define subsidy. The two cases are then compared with the method used to calculate government support in the Free Trade Agreement and with some of the main features of the recently tabled U.S. and Canadian GATT proposals on subsidies.

Regional Differences in Growth, Exit, and Entry of Farms." H. Frederick Gale, Jr., and David Henderson (ERS USDA)
Matched records from the 1978 and 1982 agriculture censuses show that gross movements of farms are much greater than indicated by net changes observed in published data. Midwestern farms have the lowest rates of exit and are most likely to grow. Southern farms have the highest exit rates and are least likely to grow.

Award-Winning Theses

Fafchamps, Marcel. "Sequential Decisions under Uncertainty and Labor Market Failure: A Model of Household Decisions in the African Semiarid Tropics." Ph.D. thesis, University of California, Berkeley, 1989.

Using household survey data collected in Burkina Faso, maximum likelihood estimates of the parameters of a stochastic, multiperiod, nonseparable, nonlinear-quadratic household model are computed. Using those estimates, the impact of technological innovations on household behavior and welfare is simulated.

Uncertainty and the absence of labor markets are shown to dramatically reduce responsiveness to market incentives, thus explaining the apparent sluggishness of African farmers that is often imputed to their asserted lack of economic rationality. They also reduce the profitability of any type of technological change.

Alternative sources of cash income are essential determinants of technology adoption because they insure the household against bankruptcy. Household labor shortages prevent the household from reaping all the benefits of technological innovations.

Finally, technological innovations are much less attractive if they induce a loss of flexibility. Many land-saving technologies are thus penalized because they are embedded into inputs whose level cannot be adjusted over the agricultural season.

Peterson, Everett B. "The Farm-Retail Price Spread Revisited: A General Equilibrium Perspective." Ph.D. thesis, Purdue University, 1989.

This study determined how economic growth and imperfect competition in domestic food manufacturing affects the farm-retail price spread. Understanding these forces is important because they circumscribe the potential impact of public policies aimed at the food system. The impact of neutral technical change and changing factor endowments in a perfectly competitive economy were analyzed. The impact of income growth on the farm-retail price is ambiguous and depends on the source of the growth. Neutral technical change in the domestic economy, except in the agricultural sector, has little impact on the farm-retail price spread. Neutral technical change in domestic agriculture caused a reduction in the price spread.

Analysis of the effect of imperfect competition in domestic food manufacturing on the farm-retail price spread highlights the role of technology and preferences. The fact that potentially imperfectly competitive industries use relatively small amounts of agricultural inputs means that they have little impact on the derived demand for agricultural products. Second, substitutability among food products by consumers determines the direction of change in the farm-retail price spread.

Standiford, Richard B. "A Bioeconomic Model of California's Hardwood Rangelands." Ph.D. thesis, University of California, Davis, 1989.

Hardwood rangelands in California and elsewhere produce multiple products. Concern about overcutting of oaks on the California ranges raises the question of whether ranchers would cut fewer oaks if they were aware of the shadow value of the trees. The study develops a bioeconomic control model to analyze the value of oak stand densities on grazing, wild life, and fee hunting revenues.

Components of the model included oak tree growth, interacting annual forage production relationships, and a hunting revenue and cost function based on livestock density and oak tree canopy. The resulting nonlinear control model showed the bioeconomic interactions; seasonal grassland production was nested within the annual controls. Uncertainty was evaluated using chance-constrained controls. The empirical problem was solved using GAMS/MINOS software for a twenty-year horizon.

The model was run for several different site-specific scenarios. The results show that knowledge of the effect of oak density on wildlife and hunting revenues increases the optimal oak tree stand and reduces cattle stocking rates.

Engel, Brian K. "Relationships between Distributions of Price Expectations Implied by Futures and Options Markets with Distributions Elicited from Farmers and Merchandisers." M.S. thesis, University of Illinois, 1989.

The general purpose of the study is to provide a greater understanding of commodity price expectations and the conditions under which farmers' and merchandisers' expectations are reflected by those implied by futures and options. The study's four specific goals are to (*a*) elicit distributions of price expectations from samples of Illinois corn and soybean producers and grain merchandisers, (*b*) describe the shape and moments of producer and merchandiser expectations as well as those implied by futures and options markets, (*c*) compare expectations across samples to determine the conditions under which futures markets reflect expectations of market participants, and (*d*) identify and measure individual characteristics that may explain differences between producers' distributions and implied distributions.

The results indicate, first, mean price expectations of producer and merchandiser groups do not differ significantly from futures prices. Second, price variances perceived by the groups differ significantly from those implied by option premia. Third, Kolmogorov-Smirnov tests for goodness-of-fit indicate that nearby distributions of the groups do not differ significantly from distributions implied by futures and options, but more distant distributions of forecasts may. Finally, the goodness-of-fit of individual distributions could not be explained by characteristics of farmers, their farms, and marketing practices through regression analysis.

Gellner, Brett M. "An Analysis of the Demand for New Wood Panels and Other Forest Products in the Canadian and U.S. Construction Industries." M.Sc. thesis, University of Alberta, 1989.

The demand for nonveneered structural wood panels (NSP) has been increasing rapidly since the late 1970s in both Canada and the United States. It is hypothesized that the demand for NSP is governed not only by relative prices and technological change but also by the increasing market acceptance of these products, giving rise to dynamic factor demand adjustments.

Three general models are used to test this hypothesis: the static, dynamic partial adjustment, and dynamic logistic model. A generalized Leontief cost function is used.

The dynamic partial adjustment with Hicks-biased technical change provides the best representation of both the Canadian and U.S. construction industries. Construction firms have not instantaneously adjusted their factors of production to long-run equilibrium levels during the historical period, an assumption that is maintained in static models and in most of the available literature on these industries.

Stiegert, Kyle. "Price Spreads and Market Structure in the Beef-Packing Industry." M. S. thesis, University of Nebraska, 1989.

This thesis develops an empirical model to test price-taking behavior in input and output markets. The model is based on the variable profit function and is used to investigate noncompetitive behavior in the farm-wholesale channel in the beef-marketing industry. A parametric test of oligopoly/oligopsony conduct is developed through the use of conjectural elasticities in the live-cattle and carcass market. The impact of the cattle cycle and technological change on the beef industry conduct was also investigated. The hypothesis of price-taking behavior in the output market was soundly rejected. Conduct in the live-cattle market suggests a regime of accommodation rather than oligopsony power as has been found in other studies.

Award-Winning Undergraduate Paper

Computer Adoption Decisions—Implications for Research and Extension: The Case of Texas Rice Producers

Anne Marie Jarvis

This study identifies the characteristics of Texas rice producers who have adopted computers relative to nonadopters. Primary survey data obtained in the spring of 1990 was examined using logit analysis to identify how each characteristic influences the probability of computer adoption. Thirty-seven percent of the respondents use computers in their business. The results indicate that as farm size and business complexity increase so does the probability of computer adoption. Some evidence that the adoption of computer technology differs from production technology surfaced. Producers' decisions to adopt a computer are associated with the actions of their peers and family. Encouraging computer user groups and computer training courses for producers could encourage the adoption of computer technology.

Key words: adoption, computer, farm management.

Each day, agricultural producers make decisions that affect their business success. Producers are forced to make choices based on incomplete information within an uncertain decision environment. Environmental concerns, biotechnology advances, government programs, and computerized information systems all contribute to the complexity of decision making (National Research Council 1987, 1989; Salassi et al.; King and Sonka). Within this dynamic decision environment, producers must allocate limited resources among competing alternatives to achieve personally established objectives (Kay). To make allocation decisions, producers rely on information obtained from many sources, such as personal experience and records, other producers, magazines, newspapers, consultants, researchers, and extension personnel.

The management of diverse information is central to sound decision making. Computers can assist users in information management. Computer hardware technology has advanced rapidly in the last forty years from mainframes to programmable calculators to affordable microcomputers (Schmidt, *Wall Street Journal*). Further, software developments have increased the potential uses of computers in farm management. Today, a wide array of software is available to support office tasks, farm budgeting, record keeping, physical production, and whole-farm planning (Sonka, Buller). Producers identify the problem, assimilate the information, select an analytical technique, and evaluate the results.

Computers provide a tool to aid in decision making; they do not make decisions for producers. Computers assist producers in performing problem solving steps more efficiently by providing information on which they can base decisions (Tucker). How many producers, however, actually use microcomputers? Previous studies indicate computer adoption rates in agriculture ranging from 2.9% to 25.6% (Willimack, Putler and Zilberman). This study identifies the percentage of Texas rice producers who use computers and identifies the characteristics of computer adopters and nonadopters through logit analysis.

Currently, efforts are underway in Texas to develop farm-level expert systems (FLEX) software for rice and cotton producers (Stone et al.). Conceptually, the FLEX program will be composed of aids for production, marketing, policy, and finance decisions. The Weed Control Advisor (WCA), the first operational piece of RiceFLEX, will soon be released (Smith). Discussions are now in progress to evaluate the possibilities for organizing a multistate effort to develop expert system software for use by southern U.S. rice producers (J. Stansel, resident director, TAMU Agr. Res. and Extens. Ctr., Beaumont, personal communication, 21 Feb. 1990). After preliminary field testing of the WCA, it became apparent that substantial diversity exists among Texas rice producers' attitudes and abilities to use microcomputers in decision-making activities (Smith). This broad range of management's potential computer use poses problems concerning how to best serve producers

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through research and extension efforts. To effectively direct future research and extension efforts concerning software development and computer training courses, computer adoption by Texas rice producers needs investigation.

In previous studies, no direct variable to quantify management's impact on computer adoption appeared. No variables to capture the influence of peers' and families' use of computers on the adoption choice have been included either. The current study develops a logit model, where computer adoption depends on several variables identified in previous research (income, equity, education, off-farming income, age, consultant use, and number of laborers) and on variables not previously included (weighted production practices index, risk management techniques used, self-perception of management skills, number of producers known who use computers, and children's influence on computer interest).

Literature Review

Several factors affect a new technology's rate of adoption (Rogers). Included are attributes of the innovation and characteristics of the individual considering technology adoption. Economic theory states that costs and benefits should be weighed before an investment is made. Both costs and benefits of computer adoption, however, are difficult to quantify. Even so, researchers have developed models to quantify the returns of computer usage to farming operations. Net present value or capital budgeting analysis can be used to evaluate the returns of an on-farm computer. This type of analysis provides depth by simultaneously considering income taxes, timing of receipts and disbursements, and interest rates (Harrison and Williams, Mackey and McCarl).

Computer technology is different from production technologies. The success of the computer within a business depends on the human capital of the manager while the success of production technology is inherent in the innovation (McGrann, Tinsley, and Lanpher). The characteristics of the manager and his operation thus directly influence the computer adoption decision. Two types of analyses have been used to study these characteristics. First, descriptive statistics create a profile of producers who use computers and those who do not. Willimack found higher gross farm income, higher debt, crop production, and corporate structure to be associated with computer use for record keeping. Nakamoto, Leung, and Marutani found computer owners to be younger, to employ more full and part-time laborers, to farm more acreage, and to make higher gross income than those producers not owning computers. Van Tassell, Kay, and Martin found crop production, more acreage, and more thorough knowledge of financial tools to be associated with computer use.

Second, qualitative choice analysis can be employed to achieve greater statistical rigor in evaluating characteristics of adopters and nonadopters (Putler and Zilberman; Lazarus and Smith; Batte, Jones, and Schnitkey). When estimating the probability of computer adoption among Tulare County, California, farmers, Putler and Zilberman found farm size, education, and producers' involvement in a sales-related business to be significant characteristics. Lazarus and Smith found education, herd size, and partnership to be significant in computer ownership for New York dairy farmers. In their study of Ohio commercial farmers, Batte, Jones, and Schnitkey found acres, age, education, record use, total expenditures on information, and grain production to be significant characteristics within their model. All the characteristics above except partnership, age, and grain production were found to increase the probability of computer adoption.

Logit Analysis

Three statistical models available to analyze binary choice problems, such as to adopt or not adopt a technology, are linear probability, logit, and probit models. Logit analysis is employed in this study for several reasons. Within a linear probability model, the predicted probability of adoption can lie outside the 0 to 1 boundary imposed on probabilities. Such a result forces arbitrary defining of outcomes which are less than 0 or greater than 1 (Judge et al., Capps and Kramer). Both logit and probit models are transformations such that a cumulative distribution is estimated, thereby eliminating the 0–1 problem associated with the linear probability model. Empirical evidence suggests that neither logit nor probit has an advantage over the other (Capps and Kramer). The choice becomes a matter of convenience (Hanushek and Jackson).

The logit model is based on the logistic cumulative probability function represented by

$$(1) \qquad P_i = F(Z_i) = 1/(1 + e^{-Z_i}),$$

where P_i is the probability that the ith decision maker selects the first alternative, $Z_i = X_i\beta$, X_i is the vector of attributes associated with the ith decision maker, β is a vector of parameters to be estimated, and e represents the natural logarithmic base (Pindyck and Rubinfeld). In this equation, Z_i can range from positive infinity to negative infinity. The probability of adoption (P_i), however, lies between 0 and 1. Because equation (1) is a nonlinear function, maximum likelihood procedures are used to estimate the parameters (Harrell).

Evaluating a logit model requires examining both goodness-of-fit measures and the estimated coefficients. One goodness-of-fit measure is McFadden's R^2, calculated as

$$(2) \qquad \text{McFadden's } R^2 = 1 - \{\text{Log } L(\hat{\beta}_{ML})/\text{Log } (L_0)\},$$

where $L(\hat{\beta}_{ML})$ denotes the maximum value of the log-likelihood function and L_0 denotes the value of log-

likelihood function when all coefficients are set equal to 0 except the intercept. Empirical evidence suggests McFadden's R^2 typically lies between 0.2 and 0.4 (Sonka, Hornbaker, and Hudson). A second measure is the likelihood ratio test, which evaluates whether a relationship exists between all of the independent variables jointly and the dependent variable. The likelihood ratio test is computed as

$$\text{(3)} \quad \text{Likelihood ratio test} = -2\,[\text{Log}\,L_0 - \text{Log}\,(\hat{\beta}_{ML})].$$

This ratio is distributed as a chi-squared random variable with $k - 1$ degrees of freedom, where k is the number of parameters in the full model.

The final test for goodness of fit is the correct classification of decision makers. To calculate this measure, first the estimated probability ($\hat{P}_i$) for each observation is obtained. Second, based on a 50/50 classification scheme, producers are classified as adopters or nonadopters. If the estimated probability is less than or equal to 0.5, then the producer is classified as a nonadopter. If the probability is greater than 0.5, then the producer is classified as an adopter. The estimated classifications are then compared to the observed adoption and nonadoption within the data set (Capps and Kramer). A table of correct classifications is presented.

The estimated coefficients are also examined. Besides sign and significance of the estimated coefficients, how a change in an attribute will affect the probability of adoption is important. Because of the nonlinear nature of the logistic function, the effect of a changing attribute on the probability of adoption is found by calculating changes in probability, which are determined by (Pindyck and Rubinfeld)

$$\text{(4)} \quad \partial\hat{P}_i/\partial X_i = [e^{\hat{z}}i/(1 + e^{\hat{z}}i)^2]\check{\beta}_i.$$

Changes in probabilities can be calculated for any combination of X_i's. The changes in probabilities are calculated, as is usually the case, by setting each independent variable equal to its sample mean.

Data Source

Farm-level data were obtained through a mail survey of Texas rice producers in the spring of 1990. The survey development process involved three testing phases in which professors, producers, county extension agents, and other agribusiness professionals reviewed the draft survey instruments and made comments. Based on a modified form of Dillman's surveying method, the surveying process consisted of three steps: (*a*) all producers were mailed surveys, (*b*) nonrespondents were mailed reminder cards, and (*c*) those producers who had not responded in step 1 or 2 were contacted by telephone or by mail. Of the 770 surveys distributed, 65 were returned by producers who indicated they no longer produced rice, and 297 were returned by current producers. Of the responding producers, 285 surveys were usable, giving a 40% response rate from producers. Usable surveys are defined as those surveys whose information concerning variables included in the logit model are complete.

Probability of Computer Adoption

This study defines computer adopters as those producers who own and use a computer in their farm management. Those producers who own computers but do not use them for business purposes are considered nonadopters. Thirty-seven percent of the producers who responded have adopted computers. This adoption percentage is considerably higher than reported in previous studies.

Characteristics Included in the Model

For clarity of discussion, the characteristics are grouped according to (*a*) socioeconomic characteristics, (*b*) management skills, (*c*) farm operations, and (*d*) computer familiarity. Included in socioeconomic characteristics are three class variables (income, equity, education) and two continuous variables (*AGE* and *OFF*). Producers' income is broken down into gross farm income under \$100,000 (*INC*1); gross farm income between \$100,000 and \$500,000 (*INC*2); and gross farm income over \$500,000 (*INC*3). Equity was segmented into those producers with less than 40% equity (*EQUITY*1), those producers with 40% to 80% equity (*EQUITY*2), and those producers with more than 80% equity (*EQUITY*3) in their farm businesses. Education was grouped into three categories also: those with less than or equivalent to a high school education (*ED*1), those who attended college (*ED*2), and those managers who graduated from college (*ED*3); *AGE* represents the age of the respondent in years; *OFF* represents the percent of off-farm income relative to total gross income from all off-farm and on-farm activities.

Two continuous variables, *INDEX* and *MGT*, and four class variables, the *CONS* group and *RISK*, comprise the management skills; *INDEX* is a weighted average of production practices representing experts' perception of how innovative a producer is in terms of physical production. For this variable, a series of questions concerning fertilizer management, water management, crop rotation, ratoon crop management, variety selection, crop development prediction, harvest moisture, and on-farm storage were asked. Researchers at the Beaumont Agricultural Research and Extension Center weighted the practices on a scale of 0 to 10 as to the importance of each practice, with 0 being the least and 10 being the most important. The weights were adjusted to reflect different practices used by producers on the east and west side of Houston (J. Stansel, personal communication, 23 Apr. 1990). How skilled producers per-

ceive themselves to be at using financial management tools and economic concepts in their business is represented by *MGT*; *RISK* measures whether a producer uses risk management tools such as crop insurance and/or futures. The *CONS* group measures consultant usage: *CONS*1 denotes whether producers use financial consultants; *CONS*2 denotes whether producers use farm management consultants, entomologists, and/or agronomists; *CONS*3 represents whether county extension agents, extension specialists, and/or research scientists are consulted.

Farm operations represent the general farm business. A set of class variables representing livestock (*LSTCK*), corn and/or grain sorghum (*CRNSORG*), soybean (*SYB*), or cotton production (*CTN*) attempts to capture diversification. A second class variable, intent of future farm size (*DECREASE, SAME, INCREASE*), is also included. Three continuous variables, number of full-time employees (*LABOR*), rice acreage (*ACRES*), and number of entities (*ENTITIES*), attempt to ascertain size and business complexity's effect on computer adoption; *ENTITIES* identifies the number of separate farm businesses in which the producer is involved.

The familiarity grouping attempts to capture the producer's familiarity with computer users through two class variables, the *NO* group and *KIDS*. The decision to adopt or not adopt an innovation is influenced by peers and family (Rogers): *NO*1 represents managers who know either no or one producer that uses a computer, *NO*2 represents managers who know two producers using a computer, and *NO*3 represents managers who know three or more producers using a computer; *KIDS* represents that children's activities have increased the manager's interest in computers.

When estimating the model, *INC*1, *EQUITY*1, *DECREASE*, and *NO*1 are dropped to avoid a singular matrix. Because the dropped variables are embodied in the intercept, the results of each category should be interpreted relative to the intercept.

Logit Results

Table 1 includes the estimated logit model, significance tests, goodness-of-fit measures, sample means, and estimated changes in probabilities. First, the overall fit of the equation is examined. McFadden's R^2 equals 0.243, which lies within the expected 0.2 to 0.4 range. The likelihood ratio test is 89.2, which is significant at a p value of less than 0.001. The estimated model correctly classified 73.8% (210 of 285) of the respondents (table 2). Examining the classification of nonadopters (specificity) and adopters (sensitivity) indicates that the model classified nonadopters (83.3%, or 149 or 179) relatively better than adopters (57.5% or 61 or 106). The better prediction of nonadopters may be attributed to the larger number of nonadopters (62%) within the data set. Overall, the goodness-of-fit measures indicate that the model fits the data reasonably well.

The respective class variable groups' significance were tested using chi-square tests with m degrees of freedom, where m is the number of parameters being tested (Capps and Kramer, Harrell). This test is similar to the F-test used in linear regression models, but because of the nonlinear nature of logit analysis, a chi-square test is implemented. In those cases involving only a single 0–1 variable, the chi-square subgroup test is equivalent to the results of the t-test for significance of the individual coefficient.

Next, the estimated coefficients are examined. Income and equity are significant within the socioeconomic characteristics. Consistent with expectations, as gross farm income increases, the probability of computer adoption increases. Contrary to Willimack's findings, the estimated coefficients suggest that as producers' equity in the farm increases, they are more likely to use a computer. This result implies that as producers increase their equity interest, they are more able and willing to make the capital investment in a computer.

Within the management skill group, *INDEX* and *CONS*2 are significant. The sign of the *INDEX* suggests rice producers who exhibit more innovative production practices are less likely to adopt computers. This result may reflect the limited availability of production-oriented software. This observation, however, appears to substantiate the concept that computer technology adoption differs from production technology adoption. Further, it may infer that those producers who concentrate on production techniques may not be as concerned with management functions such as recordkeeping, budgeting, and market tracking—all tasks for which computers offer an advantage. A negative relationship with computer adoption is reflected by *CONS*2.

Final discussion within the management skill group deals with variables which were not significant. *RISK* was intended to capture the depth of producers' economic management. The lack of significance of *RISK* confirms previous studies' findings which suggest that rice producers do not have ready access to information for effective use of the futures markets (Elms et al.) and that rice producers do not use crop insurance (Knight et al.). The expectation for *MGT* was that those producers who consider themselves better financial and economic managers would be more likely to adopt computers. The results indicate, however, that the self perception of management skills does not significantly affect the probability of computer adoption. *CONS*3 denotes that a producer uses research and/or extension personnel in making management decisions. The expectation was that research and extension personnel use should have a significant positive influence on the probability of computer adoption. The lack of significance may indicate that current methods of reaching Texas rice producers to enhance computer adoption may need some modification.

Several variables in the farm operations group are significant: *CRNSORG, CTN, LABOR, ENTITIES, SAME,* and *INCREASE*. Estimated signs on

Table 1. Logit Estimates for Computer Adoption, Texas Rice Producers, 1990

Variable	Coefficient	t-Test	Subgroup Test[a]	Changes in Probabilities[b]	Mean[c]
Intercept	−4.1472	3.08*[d]			
Socioeconomic characteristics					
*INC*2	0.6664	1.86**	6.56*	0.1536	0.53
*INC*3	1.5124	2.36*		0.3486	0.10
*EQUITY*2	0.2688	0.58	3.38***	0.0620	0.40
*EQUITY*3	0.7497	1.60*		0.1728	0.43
*ED*2	−0.4032	0.88	1.34	−0.0929	0.27
*ED*3	0.0093	0.00		0.0022	0.49
OFF	0.0004	0.00		0.0001	12.45
AGE	−0.0132	0.89		−0.0030	45.67
Management skills					
INDEX	−1.0854	1.59***		−0.2502	0.46
RISK	0.3525	1.02	1.04	0.0812	0.38
MGT	0.0804	1.09		0.0185	6.52
*CONS*1	0.0905	0.24	0.06	0.0209	0.68
*CONS*2	−0.6062	1.74**	3.11**	−0.1397	0.36
*CONS*3	0.2060	0.61	0.37	0.0475	0.59
Farm operations					
LSCTK	−0.0204	0.00	0.00	−0.0047	0.45
CRNSORG	−0.4741	1.32***	1.75***	−0.0109	0.37
SYB	−0.2034	0.53	0.29	0.0469	0.34
CTN	1.4654	1.62***	2.50***	0.3378	0.04
LABOR	0.1679	2.03*		0.0387	2.40
ACRES	0.0002	0.70		0.0000	491.34
ENTITIES	0.1954	1.52***		0.0451	1.59
SAME	1.2029	1.86**	4.72**	0.2772	0.67
INCREASE	1.3951	1.97*		0.3216	0.21
Computer familiarity					
*NO*2	0.6058	1.08	8.00*	0.1396	0.15
*NO*3	1.1430	2.69*		0.2634	0.61
KIDS	0.9442	3.11*	9.91*	0.2176	0.44
McFadden's R^2				0.243	
Likelihood ratio test (26 degrees of freedom)				89.2*	
Number of observations				285.0	

[a] Chi-square test of full versus reduced models.
[b] Computed at sample means [see equation (4)].
[c] Calculated sample mean for both adopters and nonadopters.
[d] Single asterisk indicates significant at a p value of .05 or less; double asterisk indicates significant at a p value of .10 or less; triple asterisk indicates significant at a p value of .20 or less.

Table 2. Comparison of Observed and Estimated Computer Adoption, Texas Rice Producers, 1990

		Estimated		
		Nonadopters	Adopters	Total
Observed	Nonadopters	149	30	179
	Adopters	45	61	106
	Total	194	91	285
Correctly classified (210 out of 285)			73.8%	
Sensitivity (61 out of 106)			57.5%	
Specificity (149 out of 179)			83.3%	

CRNSORG and *CTN* reflect the nature of production. Management requirements to produce corn and/or grain sorghum are not generally as strenuous as those for rice or cotton. Therefore, the negative relationship with *CRNSORG* is consistent with information and management demands. In contrast, cotton demands high variable and fixed input costs. These high costs apparently encourage producers to closely monitor production, marketing, and financing in order to increase their profit margins. Consequently, the pos-

itive parameter for *CTN* suggests that producers producing cotton are more likely to adopt computers. As an indication of size and complexity, *LABOR* and *ENTITIES* exhibit a positive relationship with computer adoption. If producers intend to maintain or increase farm size, they are more likely to adopt a computer. This relationship suggests that producers who are going to continue to farm rice may recognize the computer's importance as an information assimilating and analyzing tool.

The computer familiarity group extends the scope of this study into areas not previously investigated. Social interaction as an influence in computer adoption (Rogers) is affirmed by the significant positive coefficients on variables *NO*3 and *KIDS*. These results indicate that producers are influenced by the actions of their peers and family. *NO*3 suggests that managers who know three or more producers using computers for their businesses are more likely to adopt computer technology. Producers whose children have experience with computers and who acknowledge this experience has increased their own interest in computers are more likely to use computers. When considering this relationship, it is important to keep in mind that those respondents who own computers only for their children's use are not considered as adopters.

The nonlinear nature of logit analysis requires that equation (4) must be used to estimate how an attribute will change the probability of computer adoption. Table 1 also includes the calculated changes in probabilities and the means on which the changes of probabilities are based. The interpretation of changes in probabilities for *INDEX*, for example, is as the value of *INDEX* increases one unit, the probability of computer adoption decreases 25.02% (O. Capps, Dep. Agr. Econ., Texas A&M University, personal communication, 31 May 1990). The remaining changes in probabilities given in table 1 have similar interpretations.

Conclusions and Implications

In times of increasing complexity in farm management, computer adoption reflects producers' attempts to better assimilate and utilize information. The 37.1% of Texas rice producers participating in the management survey who use computers in their management activities is greater than the percentages reported in previous studies. As size and complexity within the farming operation increases, the probability of computer adoption increases. Some confirmation that a difference exists between production technology and computer technology surfaced through the sign and significance of *INDEX* and *CONS*2. Those producers who intend to maintain or increase their operation's present size are more likely to adopt computers. The positive relationship between number of peers using computers and children's experience with computers offers insight into possible enhancement of computer usage.

Assuming a goal of research and extension is to increase computer adoption among producers, two main implications can be derived. These implications involve production management and familiarity. McGrann, Tinsley, and Lanpher contend that the decision to adopt computer technology is different from production technology. Comparing innovations within the Texas rice producing sector further confirms this position. For example, semidwarf varieties were introduced in 1983 (Texas Agricultural Experiment Station); Texas rice producers planted 88% of their acreage to semidwarfs in 1989 (*Rice Journal*). In comparison, affordable microcomputers were introduced in 1977 (*Wall Street Journal*); only 37% of the respondent group in this study have adopted computers. The visibility of an innovation and its apparent relative advantage influence its rate of adoption (Rogers). Other producers can witness a manager's production practices with semidwarfs and the resulting physical yield. Computers and their intangible values are not as observable. The difficulties in quantifying microcomputer costs and benefits make the relative advantage of computer adoption difficult to ascertain. Therefore, further research may be needed to more effectively quantify returns from microcomputer use.

Another feasible approach would be to focus on the familiarity aspect of computers. Resources may need to be diverted from software development into computer literacy programs. Encouraging computer users' groups among producers could increase the visibility of returns associated with computers use. That is, if some producers realize increased returns from using computers in their management activities, other producers may be more willing to adopt computers themselves. Encouraging computer skills for children is another possible way to reach producers. Extension specialists might consider working in conjunction with schools and youth groups to develop computer training programs.

Traditional research and extension methods to disseminate technology may not be functioning as well with microcomputers compared to production technologies. The intent here is not to advocate that everyone adopt a computer. As called for by McGrann and Breazeale, however, more information would be useful in regard to computer use in Texas agriculture. This study responds to that call with respect to Texas rice producers. Beyond apparent research and extension uses of this information, private sector hardware and software vendors seeking to assist the agricultural community may be served by the findings of this study.

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Abstracts

"Optimal Advertising Budget for the Ontario Milk Marketing Board." Paula Conboy (University of Guelph), second-place paper.

In the last few years, the Ontario Milk Marketing Board has become quite active in fluid milk advertising, in an attempt to increase its market share of the nonalcoholic beverage market. To date, theoretical optimal advertising rules have been developed assuming advertising expenditures are a fixed cost. However, in Ontario, where such expenditures are financed through producer levies, the expenditure might more appropriately be regarded as a variable cost to the producer. In this study, a theoretical optimal advertising rule is developed and a suggested advertising expenditure for 1988 is derived. The research uses both synthetic and an estimated empirical model to determine this optimal level.

The result of the analysis suggests that the Ontario Milk Marketing Board's revenue net of advertising costs could be substantially increased if advertising is considered a variable cost when setting an optimal budget for advertising of fluid milk.

"Pricing Efficiency and Hedging Effectiveness in the Flaxseed and Rapeseed Futures Markets." David Thacker (University of Alberta), third-place paper.

This paper empirically assesses the forward pricing efficiency and producer hedging effectiveness of the flaxseed futures market as compared to the rapeseed futures market. Two tests of forward pricing efficiency relating to the forecasting accuracy of both markets are performed. The effectiveness of producer hedging in both markets is also investigated, with an estimation of the optimal hedge ratio and reduction in price variability resulting from hedging.

AAEA Business

Committee Reports

Report of the President

This year has been unique for the association, and as it concludes, future challenges are apparent.

This year, the resignation of Bruce Gardner as president-elect necessitated two elections for president-elect: one to fulfill Gardner's unfinished term, another for the normal transition of association officers.

North Carolina State University has informed the AAEA Executive Board that they have reluctantly reached the conclusion that they will be unable to host the AAEA meetings in 1993. They stated that "the facilities at Raleigh pose a number of problems . . . [that they] suggest we could have a high probability of an unfavorable experience for the Association." The board is currently considering alternative sites.

The ad hoc Adaptive Planning Committee has produced an important document that should prove to be an important catalyst to the association's long-range planning. Their excellent work will encourage us to focus on the issue of "what type of association do we want to be as we enter the next century?" Their report is thus a beginning, not a conclusion. Their report will be discussed in a symposium Monday at 3:30 P.M. in Buchanan A-106. All are welcome. The deliberations they have started will continue over the next year, but the committee and board need your opinions on the wisdom of and mechanisms for the broadening of the appeal of the association.

By all historical precedent, the Vancouver meetings are quite a success. Attendance of professionals is a recordbreaking 1,593. Total registrants are 2,325. We had over 685 reviewed papers and, even though more papers than usual were selected because of the additional meeting day, the acceptance rate decreased from 59% to 49%. Poster competition, in its third year, continues to be well received. This year we have 52 posters. The extra day allowed for more symposiums (57) to be accepted and for better integration with the Canadian Agricultural Economic and Farm Management Society, Western Agricultural Economics Association, and the Association of Environmental and Resource Economics.

After much success with pre- and post-conferences, we are evaluating this meeting, and we welcome comments. Thanks are due to Josef Broder for conducting this evaluation. You will find in your registration packet an evaluation sheet—please fill it out and return it as indicated. We will report the results in a forthcoming *AAEA Newsletter*.

We are experimenting with providing better continuing education experiences within the context of the regular meeting dates. Our first event, developed by the Professional Activities Committee and entitled *Nonmarket Valuation: Extending the Frontiers and New Applications*, has more than 230 registrants, so we know the interest is high. We plan to have another learning seminar next year. We also have good participation in our excellent preconferences: AAEA/CAEFMS; Agriculture and Rural Restructuring; Comparisons of the United States, Canada, and Europe; and Challenges for Extension Economists in the 1990s.

I owe thanks to many for this year. The AAEA Business Office staff, particularly Charlene Carsrud and Lona Christoffers, have been of great assistance throughout my presidency, as has our secretary-treasurer, Ray Beneke. My assistant, Debra Thunberg has been essential to the smooth functioning of the association business throughout the year. Both John Miranowski and Richard Perrin have completed their terms as board members, and both deserve special thanks for their excellent service. John has taken many special assignments in addition to the normal board responsibilities; Dick has been chair of the Finance Committee in a year when I have been requesting a major reexamination of the reporting format and board financial policy. He and his Finance Committee, as well as our secretary-treasurer, have contributed many hours to association business. Les Manderscheid will no longer be serving on the board; his term as past-president ends as mine begins. He has been most helpful in my transition from president-elect to president. My appreciation is also expressed to all the AAEA Executive Board members and editors; they have provided excellent counsel. It has been an honor and a privilege to serve as president of AAEA.

Sandra S. Batie, president

Report of the Secretary-Treasurer

The AAEA Business Office has worked with the Finance Committee in an effort to tell the association's financial story a bit more succinctly, and hence more comprehensibly, than in past years. The central theme of the story we have to tell is that the endowment created by astute financial management on the part of our predecessors have enabled the organization to support generously two exciting projects, The AAEA Foundation and *CHOICES*, without subjecting the financial health of the association to unacceptable risks. The association has nurtured the foundation during its start-up years with significant contributions to the latter's operating expenses. As the foundation becomes more robust, this subsidy will become less critical to its survival and progress. During the last

year, the association has paid a larger portion of the cost of publishing *CHOICES* because, as planned, other subsidies have decreased. In view of the fact that *CHOICES* has been so well received, it likely will be an important association activity for years to come. Thus, we can expect AAEA costs of supporting *CHOICES* to increase as other sources of financial support dwindle.

Not only are we fortunate as an organization in having a substantial endowment to help support our activities, but we have the good luck to have our portfolio perform well. Under the leadership of Chet Baker, William Tomek, Leo Polopolus, David Lins, and Ken Krause, the association in 1984 undertook a thorough analysis of alternatives for managing our portfolio and in 1985 placed our investments in the hands of the American National Bank of Chicago. After a lackluster beginning, this organization has performed well for us. You will note that about 50% of our assets of late have been in common stock. I want to point out that during 1989 our income from dividends, interest, and gains from sale of stock totalled $87,300. The good news is that this performance kept us well in the black for 1989. The bad news is that we face substantial deficits in 1990 and 1991. I have generously left explanations of how we propose to cope with these deficits to my good friend, Richard Perrin.

One trend that has been obvious during my six years as secretary-treasurer is the increasing resistance we as an organization face in attempting to coax subsidies from other organizations to support association activities. In past decades we have asked board members and others serving the association to obtain funds for travel expenses from their employing institutions or pay the bills themselves. This approach is more difficult to sell now than twenty years ago. Likewise, it is becoming more difficult to entice universities to hose our annual meetings and, unlike the situation of by-gone days, when they do agree to serve as hosts, universities are unwilling to provide extravagant subsidies in the form of unpaid support personnel and rent-free facilities.

I am pleased to tell you the Business Office has functioned with *esprit de corps* and competence as we have added more and more foundation activities to our mission and have added to the scope of the Employment Service. In addition, in recent years we have taken more responsibility in the business office for planning the annual meetings. The meetings have been a challenge for all of us this year; not everything has gone as we would have liked, but the Vancouver

Table 1. AAEA Budgets: 1990, 1991

	1990 Budget Approved 8/89	1990 Budget Revised 8/90	1991 Budget Approved 8/90
		($)	
INCOME			
OPERATING INCOME			
TOTAL MEMBERSHIP DUES INCOME	193,700	188,460	250,000
Publications			
Total *AJAE* income	171,000	179,000	166,000
Total *Newsletter* income	19,200	18,800	17,800
Total *Choices* income	98,000	80,000	72,000
TOTAL MEETINGS INCOME	15,000	5,000	7,500
TOTAL OTHER INCOME	10,900	10,340	11,560
TOTAL OPERATING INCOME	507,800	481,600	524,860
EXPENSES			
OPERATING EXPENSES			
Publications expense			
Total *AJAE* expenses	217,800	212,000	234,200
Total *Newsletter* expenses	21,100	21,100	21,100
Total *CHOICES* expenses	168,000	166,000	180,000
TOTAL PROJ, COMM, MBR SERV EXPENSES	17,200	15,740	33,260
TOTAL MEETING EXPENSES	500	500	500
TOTAL EXECUTIVE BOARD EXPENSES	22,500	18,000	22,500
TOTAL EMPLOYMENT SERVICE	14,000	14,000	15,000
TOTAL BUSINESS OFFICE EXPENSES	97,600	95,100	102,200
TOTAL INVESTMENT EXPENSE	9,500	9,500	9,500
TOTAL OTHER EXPENSES	13,100	18,000	14,000
AAEA FOUNDATION	10,000	10,000	10,000
AAEA STUDENT SECTION	500	1,500	1,500
TOTAL OPERATING EXPENSES	591,800	581,440	643,760
NET OPERATING INCOME	(84,000)	(99,840)	(118,900)
TOTAL INVESTMENT INCOME	51,000	90,500	49,000
NET INCOME	(33,000)	(9,340)	(69,900)

adventure has provided a first-rate learning experience. Planning annual meetings not hosted by a university and hence not using generous amounts of personnel from the host institution makes heavy demands on the business office staff. We recognize that such meetings are the wave of the future, and we are developing the skills to accommodate them.

I would like to commend Lona Christoffers, our administrative coordinator, on the competent and enthusiastic service she has rendered the association during the past year. She has been unfailingly helpful, kind, and courteous in her professional contacts and has made many friends for the association. Charlene Carsrud has had an especially busy year in coordinating plans for the meeting this year because of the added complexities involved in meeting outside the United States. As some of you know, the association pays Charlene on a quarter-time basis—which, given the work she does, amounts to a highly productive investment for the association. She has developed into an expert on planning meetings. Jaye Stefani, who has major responsibility for the Employment Service, has worked patiently and persistently to serve more members and to make the operation a viable year-round factor in the job market.

Thus, the Business Office staff continues to serve creatively and diligently. As a group our staff members thrive on responsibility and welcome new challenges. If you have suggestions on how we can better serve the association, please share them with any of us.

Raymond R. Beneke, secretary-treasurer

Report of the Tellers Committee

Ballots for the elections of the AAEA Executive Board and the AAEA Foundation Governing Board were sent to and collected from the association members by the AAEA Business Office and secretary-treasurer and counted by the Tellers Committee in accordance with the constitution and bylaws.

The successful candidates were:

President-elect:	Bruce R. Beattie
Directors of the executive board:	Brady J. Deaton Katherine H. Reichelderfer
Members of the Foundation governing board:	Bruce F. Johnston John E. Lee, Jr.

A total of 3,826 packets of election materials were mailed to eligible members, compared to 3,924 in 1989 and 3,809 in 1988. There were 1,773 ballots returned by the 15 June deadline for a response rate of 46.3%. The response rate is down from the approximate 50% level of the previous three years. All ballots returned before the deadline were counted.

Daniel Otto, chairperson

Report of the AAEA Finance Committee

During the period August 1989–July 1990, the membership of the AAEA Finance Committee consisted of Walter Armbruster (Farm Foundation), David Barkley (Clemson University), Raymond Beneke (AAEA secretary/treasurer), Steven Hanson (Michigan State University), David Kohl (Virginia Polytechnic Inst. & State University), Michael Mazzocco (Texas A&M University) and Richard Perrin (N.C. State University).

The financial base of the association remains strong, as reflected by the financial reports. During 1989, total equity of the AAEA (with portfolio at market value) increased by nearly 20%, to a little over $1 million, and the additional 4.5% increase in portfolio value during the first six months of 1990 increased this equity even further.

However, several considerations suggest that this picture of robust financial health is misleading. First, the portfolio gains could easily by reversed with a decline in the market. Second, despite the improved equity position, we experienced a much smaller increase in the value of the general fund (we experienced a loss with portfolio valued at cost), which is a better measure of the unencumbered resources of the association. Third, operating expenses exceeded operating revenue by $72,270 in 1989, after a surplus of $37,136 in 1988. Projections indicate a larger deficit for 1990 and larger yet for 1991.

The reasons for this increasing operating deficit are that prices have risen during the past five years while dues have not, the association has undertaken an increasing share of the cost of publication of *CHOICES* during this period, and the association has been providing increasing services to the membership.

In response to this situation, the AAEA Executive Board has adopted the policy that 3% of the value of association equity is to be used to meet operating expenses, and recommended a 33% increase in dues. The membership approved this increase. While one-time expenditures for moving the *AJAE* offices and for publishing a membership handbook will cause another operating budget deficit in 1991, the financial projections for the next two years are much improved.

Richard K. Perrin, chairperson

Report of the *AJAE* Editor (1989–90)

This report marks the close of the fourth year of operations for the Illinois editorial office of *AJAE*. During the past year we accomplished a smooth transition in journal printing from Heffernan Press to Edwards Brothers in Ann Arbor, Michigan. The results for AAEA members and subscribers have been improved timeliness in publication of the *Journal* and lower publication costs. Contributing to timeliness is the shift in printing of the proceedings of the winter meetings from the May issue to the August issue.

New submissions of manuscripts in the most recent twelve-month period (1 July 1989 to 30 June) totaled 370 manuscripts, equaling the record high of two years ago. These submissions continue to reflect strong support from international authors, economics departments, business schools, agencies, and institutes, as well as the traditionally significant source of new submissions from agricultural economics departments in land grant universities. These submissions are heavily dominated by research-oriented manuscripts, although a respectable number of extension, teaching, and other nonresearch pieces are received as well. Basically, the mix of published articles reflects the mix of submitted material, with the dominance of research-oriented articles following through from submission to publication.

We have continued to emphasize timeliness in the handling of manuscripts, as indicated by the frequency distributions and averages of handling times for the various submission categories of manuscripts and reviewers reported in table 1. During the past year, the response times on the original submission averaged 70 days, with a response on 77% of these occurring within a 90-day period, 93% within 120-day period, and 99% within 150 days. The average response times on second and third submissions were 26 days and 4 days, respectively. Table 1 also indicates a frequency distribution for reviewer response times for each submission category. The average response times of reviewers on the initial submission was 48 days, with an average of 45 days for second submissions.

During 1990, we will publish 92 articles, 8 comments and 6 replies in volume 72 of the *Journal* for a total of 106 refereed items. The publication rate is 29% of the manuscripts submitted during the year. Besides the refereed material, the August 1990 issue will contain 21 invited papers and discussions from the winter meetings and the December issue will contain the invited papers, discussions, addresses, and other related items from the 1990 meetings.

The 1990 volume will also contain sixty-one book reviews under the excellent leadership of Dale Adams, the book review editor. The range of books under review continues to be broad in terms of subject matter, style, and global perspective.

The operating expenses of the Illinois editorial office of *AJAE* totaled $31,514 over the twelve-month period from 1 July 1989, to 30 June 1990. The office has continued to operate in a cost effective manner, and the support provided by the Department of Agricultural Economics at the University of Illinois is appreciated.

Other special activities of the editor during the past year included (*a*) the development of guidelines for data availability and documentation of research procedures that now is published as item 5 on the inside of the back cover of the *Journal*. The text of the guideline is

> Authors are expected to document their data sources, models, and estimation procedures as thoroughly as possible, and to make data used in their analyses available to other researchers for replication purposes. If for legal or proprietary reasons, the data cannot be made available to all potential users, this limitation should be noted. Submission of appendices, model documentation, and other supporting materials with the manuscript is acceptable in order to facilitate the review process.

(*b*) the development of a storage policy for back issues of the *Journal*, and (*c*) revisions in the eligibility requirements for participation in the outstanding *AJAE* article award, that basically allows articles by asso-

Table 1. Response Times for Manuscripts and Reviewers, 1989–90

	Manuscripts[a]			Reviewers[b]		
Days	Submission One	Submission Two	Submission Three	Submission One	Submission Two	Submission Three
	(%)					
0 to 15	6	56	97	6	4	0
16 to 30	3	6	0	17	21	36
31 to 45	9	10	3	26	32	32
46 to 60	27	19	0	29	23	18
61 to 75	18	2	0	10	8	9
76 to 90	13	2	0	5	6	0
91 to 105	9	4	0	3	2	5
106 to 120	7	2	0	2	2	0
121 to 135	5	0	0	1	1	0
136 to 150	1	0	0	1	0	0
Over 150	1	0	0	0	0	0
Total	100	100	100	100	100	100
	(days)					
Average	70	26	4	48	45	41

[a] Number of days from the receipt of a manuscript in the editorial office until an editorial response is mailed to the author.
[b] Number of days from the date of mailing to a reviewer to the date a response is received in the editorial office.

ciate editors and previous award winners to be considered each year. The results of each of these activities were approved by the AAEA board.

The board of associate editors has continued to provide timely and high quality evaluations of manuscripts, counsel on matters affecting *Journal* policy, and participation in the selection of the outstanding *Journal* article award. The board's support is invaluable to the operations of the editorial office and to the quality of content of the *Journal*. During the past year, associate editor Bruce Gardner concluded his term of service and we welcome the addition of Julian Alston to the board of associate editors. Besides the 20-member board, we also involved more than 550 individuals in the manuscript review process, some providing several reviews. Their names are listed in an appendix to this report. Other continuing and productive members of the editorial staff include editorial assistants Phyllis Blackford and Donna Cline, technical editor Martha Luzader, and senior associate editors Phil Garcia and John Braden.

Thank you very much.

Peter J. Barry, editor

Appendix

Reviewers, July 1989 to July 1990

Philip C. Abbott
David Abler
W. L. Adamowicz
Richard M. Adams
Adesoji O. Adelaja
Mary Ahearn
Vedat Akgrivay
Jay Akridge
Harold Alderman
Mubarik Ali
Julian Alston
Carl Anderson
James L. Anderson
Jock Anderson
Lee G. Anderson
John Antle
Frances Antonovitz
Farshad A. Araghi
Pier Giorgio Ardeni
Walter J. Armbruster
Carlos A. Arnade
Louise Arthur
Emerson Babb
Bruce Babcock
F. S. Bagi
Timothy Baker
Dean Baldwin
Nicole Ballenger
Richard R. Barichello
Alan D. Barkema
Randloph Barker
Andrew Barkley
David Barkley
Scott W. Barnhart
Phillip Baumel
Bruce R. Beattie
John Beghin
Michael Belongia
Bruce L. Benson
Peter Berck
Olvar Bergland
John Bergstrom
Dan Bernardo
G. Andrew Bernat
David Bessler
Ronald Bewley
Arlo Biere
James Binkley
Hans P. Binswanger
Richard C. Bishop
Leroy Blakeslee
Steven Blank
James Blaylock
Don Blayney
Alan S. Blinder
Barry Bobst
Nancy E. Bockstael
William Boggess
Douglas R. Bohi
Richard Boisvert
James T. Bonnen
Kevin Boyle
John R. Braden
Garnett Bradford
John Brake
Jon Brandt
Boris E. Bravo-Ureta
Maury E. Bredahl
Josef M. Broder
Daniel W. Bromley
Wade Brorsen
Deborah Brown
Keith Bryant
Steven Buccola
J. Bruce Bullock
Joseph Buongiorno
Allison Burrell
Oscar Burt
Rueben C. Buse
Walter Butcher
Derek Byerlee
Peter H. Calkins
Susan Capalbo
Oral Capps
Gerald Carlson
Hoy Carman
C. A. Carter
Michael Carter
Kenneth Casavant
Emery N. Castle
Margriet F. Caswell
Lon Cesal
Ujjayant Chakravorty
James Chalfant
Robert G. Chambers
Ching-Cheng Chang
Duane Chapman
Jean-Paul Chavas
Dean Chen
Raj Chhikara
E. Kwan Choi
Suengmook Choi
Mark J. Cochran
Garth Coffin
Robert Collender
Phil L. Colling
Neil Conklin
John R. Conlon
John Connor
Richard Connor
Edward C. Cook
Stephen Cooke
Ronald W. Cotterill
Thomas Cox
Barry Coyle
Gail Cramer
Keith Criddle
John B. Crihfield
Stephen R. Crutchfield
Carlos Cuevas
Roger Dahlgran
Dana G. Dalrymple
Rachel Dardis
P. J. Dawson
Richard Day
Larry DeBoer
David Debertin
Christopher Delgado
Mark Denbaly
William H. Desvousges
Harry de Gorter
Barbara Devaney
Gary Devino
John Dillon
Praveen M. Dixit
Bruce L. Dixon
Gerald Doeksen
Otto Doering
Arthur J. Dommen
Jeffrey Dorfman
Folke Dovring
Diane P. Dupont
John Dutton
James S. Eales
J. E. Easley
David B. Eastwood
Mark Edelman
Vernon Eidman
Emmett W. Elam
Robert Emerson
James Epperson
David Ervin
Terry Ervin
Hadi Esfahani
Don Ethridge
Robert Evenson
Paul Fackler
Walter P. Falcon
Barry Falk
Richard Fallert
Merle Faminow
Shenggen Fan
Rolf Färe
Richard L. Farnsworth
Donald Farris
Allen Featherstone
Gershon Feder
Israel Finkelshtain
Martin L. Fischer
Anthony C. Fisher
Jerry Fletcher
Stanley M. Fletcher

Appendix (Continued)

Ray Folwell
Olan Forker
Lynn Forster
William E. Foster
Glenn Fox
Michael Frank
John Freebairn
A. Myrick Freeman
Ben C. French
Edward O. Fryar
Lilyan Fulginiti
Murray Fulton
Gene Futrell
Paul Gallagher
B. Delworth Gardner
Bruce Gardner
Edward Gbur
Mary Gerlow
Joe Glauber
Ellen Goddard
E. Bruce Godfrey
D. L. Good
Barry Goodwin
Barry Goss
Theodore Graham-Tomasi
Dwight Grant
Warren Grant
Richard Green
Clyde Greer
Thomas Grennes
Ron Griffin
Faruk Guder
David Guilkey
Harold D. Guither
Russell Gum
Lewell Gunter
Cole Gustafson
David Hahn
Richard Haidacher
Catherine Halbrendt
Darwin C. Hall
Harry Hall
Arne Hallam
Joel R. Hamilton
Jeoffrey Hammer
Michael Hanemann
Tassos Haniotis
Greg Hanson
Steven Hanson
Sermin Hardesty
Neil Harl
Carolyn R. Harper
Thomas Harris
Zuhair A. Hassan
L. Upton Hatch
Robert J. Hauser
Arthur Havenner
Yujiro Hayami
Marvin Hayenga
Dermot Hayes
Peter Hazell
Dale Heien
Richard G. Heifner
Gloria Helfand
Peter G. Helmberger
Glenn Helmers
M. S. Henry
Robert W. Herdt
Thomas Hertel
Lowell D. Hill
Eithan Hochman
Ian Hodge
John P. Hoen
Garth J. Holloway
John Holt
Matthew Holt
Duncan Holthausen
Robert H. Hornbaker
James Houck
Charles W. Howe
James Hrubovcak
Chung L. Huang
Kuo Huang
Michael A. Hudson
Ray G. Huffaker
Wallace Huffman
Leroy J. Hushak
Robert D. Innes
Scott H. Irwin
Cathy Jabara
Lovell Jarvis
Helen Jensen
Kimberly Jensen
Edward Jesse
Per-Olov Johansson
Gale Johnson
Paul Johnson
Sam H. Johnson
Stanley R. Johnson
Thomas Johnson
Thomas Johnson
Bruce Johnston
Richard M. Johnston
Warren E. Johnston
Bruce L. Jones
Lonnie C. Jones
Timothy E. Josling
Richard Just
K. H. Kahl
Harry Kaiser
K. P. Kalirajan
Larry Karp
Ronald Kay
Michael Kaylen
Mary Jo Kealy
John Keith
Lawrence Kenny
Richard Kilmer
Robert P. King
Henry Kinnucan
Jean Kinsey
Catherine Kling
Keith Knapp
Tom Knight
Mary K. Knudson
Ron Knutson
Ulrich Koester
William Kolberg
Won W. Koo
Carol S. Kramer
Randall Kramer
Alan J. Krupnick
Jeffrey LaFrance
Ronald Lacewell
George Ladd
Sylvia Lane
Max R. Langham
John S. Lapp
Bruce Larson
Douglas Larson
Robert G. Lawrence
William Lazarus
Michael LeBlanc
Howard Leathers
David Lee
Hynok Lee
Jong-Ying Lee
Linda Lee
Tsoung-Chao Lee
Warren F. Lee
Catherine Lemieux
M. L. Lerohl
William Lesser
Raymond M. Leuthold
Erik Lichtenberg
Justin Yifu Lin
William Lin
Robert K. Lindner
David A. Lins
Douglas Lipton
Donald J. Liu
John B. Loomis
Ramon Lopez
Rigoberto A. Lopez
Gary Lynne
Charles Lyon
Carl Mabbs-Zeno
Edwin D. Maberly
Mark Machina
Harry Mapp
Bruce Marion
Michele Marra
John Marsh
Marshall Martin
William E. Martin
Michael A. Mazzocco
Alex McCalla
Francis McCamley
Bruce A. McCarl
Kenneth A. McConnell
Vicki McCracken
Tom McGuckin
Chris McIntosh
Christopher McIntosh
John McKean
Edward McLaughlin
William T. McSweeny
Karl Meilke
John W. Mellor
Robert Mendelsohn
Guillero Mendoza
Dale Menkhaus
Fredric C. Menz
Jack Meyer
Richard L. Meyer
William Meyers
John R. Miller
S. E. Miller
Thomas A. Miller
Tracy C. Miller
J. Walter Milon
Mario J. Miranda
Ron Mittelhammer
James Mjelde
Joe Moffitt
Eric Monke
Giancarlo Moschini
Charles Moss
Timothy Mount
Yair Mundlak
Warren Musgrave
Wesley N. Musser
Robert Myers
Charles H. Nelson
Gerald C. Nelson
Ray D. Nelson
Marc Nerlove
David M. G. Newbery
John Nichols
David Nielson
Richard Norgaard
George Norton
James Oehmke
Susan E. Offutt
Alan L. Olmstead
Hayri Onal
David Orden
Tim Osborn
Daniel Otto
Philip Paarlberg
Daniel Padberg
Angelos Pagoulatos
Emilio Pagoulatos
Ray Palmquist
Sushil Pandey
Philip G. Pardey

Appendix (Continued)

Quirino Paris	James Richardson	Stephen M. Smith	Odell Walker
William M. Park	Ed Rister	Steven T. Sonka	Nicholas A. Walraven
E. C. Pasour	Lynn Robbins	Kim Sosin	Ron Ward
George Patrick	John C. Robertson	Thomas H. Spreen	Peter G. Warr
Scott Pearson	Lindon J. Robison	Dale Squires	Courtland Washburn
Anne E. Peck	M. Henry Robison	T. N. Srinivasan	Myles Watts
Glenn Pederson	Abelardo Rodriguez	Bernard Stanton	David Wear
John Penson	Terry Roe	Spiro Stefanou	Robert D. Weaver
Jeffrey M. Perloff	Mark W. Rosegrant	Thanasis Stengos	Alfons Weersink
Richard Perrin	James Roumasset	Richard P. Stillman	Cathy Wessels
Gregory M. Perry	Jeffrey S. Royer	John Stoll	Paul Westcott
Wesley Peterson	Randal Rucker	Ivar Strand	Randall Westgren
Michel J. Petit	C. Ford Runge	John Strauss	Michael E. Wetzstein
Todd E. Petzel	Vernon Ruttan	Daniel A. Sumner	Glen Whipple
Truman P. Phillips	Larry Salathe	Earl Swanson	Fred C. White
Tim T. Phipps	R. K. Sampath	Philip Szemedra	Marilyn Whitney
Daniel Pick	Gerald Schluter	Steve Taff	Norm Whittlesey
Leo Polopolus	Allan A. Schmid	Stefan Tangermann	Tom Wiens
Greg Pompelli	Andrew Schmitz	Loren Tauer	James E. Wilen
Rulon D. Pope	Gary Schnitkey	C. Robert Taylor	Lois Willett
Barry M. Popkin	Lee Schrader	Daniel Taylor	Elizabeth Wilman
Nicholas Powers	Ronald Schrimper	J. Edward Taylor	William W. Wilson
Paul Preckel	Ted Schroeder	Timothy G. Taylor	Michael Wohlgenant
David Prescott	Bryan Schurle	Gary Thompson	Brian Wright
Warren Preston	Nancy E. Schwartz	Sarahelen Thompson	Bryan Wright
David Price	Grant M. Scobie	Stanley R. Thompson	Michael Wyzan
Glen C. Pulver	John T. Scott	Walter Thurman	John Yanagida
Daniel S. Putler	Kathleen Segerson	C. Peter Timmer	Robert Yonkers
John Quiggin	Wesley D. Seitz	William G. Tomek	Pan A. Yotopoulos
Alan Randall	Ann H. Seitzinger	James Trapp	Doug Young
Vithala R. Rao	Ben Senauer	Russell E. Tronstad	Nathan Young
Philip Raup	Richard J. Sexton	Marinos E. Tsigas	Robert A. Young
Gordon C. Rausser	Leonard Shabman	Francis Tuan	Trevor Young
Martin Ravallion	Carl Shafer	Stephen Turnovsky	Thomas Zacharias
Daryll Ray	James D. Shaffer	Calum Turvey	Hector Zapata
Thomas Reardon	Robert J. Shiller	Luther Tweeten	Kelly Zering
Michael Reed	J. Scott Shonkwiler	Thomas Ulen	David Zilberman
Katherine Reichelderfer	James S. Shortle	Laurian Unnevehr	Pinhas Zusman
Donald W. Reid	Richard Shumway	G. C. Van Kooten	
Mitch Renkow	Terry Sicular	Eileen O. van Ravenswaay	
R. Bruce Rettig	Jerry Skees	Michele Veeman	
Timothy Rhodus	David Smallwood	Harold von Witzke	
Marc Ribaudo	Kerry Smith	Thomas I. Wahl	

Report of *CHOICES* Editor

The four 1989 issues of *CHOICES* included material prepared by 136 authors, the same number as in 1988. As in earlier years, several, but not all, authors were members of the association. From the beginning of *CHOICES* in 1986, authors who are not members of the association have been welcome participants in the dialogue in *CHOICES*.

Circulation of the magazine at the end of 1989 was slightly over 14,000. Subscriptions have declined somewhat since then as less effort was focused on the promotion of subscriptions. The association continues to receive substantial financial support for *CHOICES* from USDA agencies and from university deans, many of whom purchase group subscriptions to send to clientele in their respective states.

Arrangements for subscription fulfillment that were initiated in 1989 continue. These activities are carried out by the AAEA Business Office at Ames.

The editor receives manuscripts, works with the advisory council in selecting material for the magazine, and directs the preparation and the mailing of the magazine.

There continues to be a need for more short articles. In addition, during the coming months there will be significant efforts made to attract more authors from other countries.

A Kellogg Foundation project is being conducted jointly by the American Agricultural Economics Association and the American Agricultural Editors' Association. The project activities are closely related to *CHOICES*.

Under the auspices of the project, press releases have been prepared and distributed on eleven articles which appeared in the fourth 1989, and first and second 1990 issues of *CHOICES*. In addition, press conferences were held when each of these issues was released. A backgrounder for agricultural press people focused on "The Evolution of Food, Farm, and Resource Policy" was held in April 1990 in St. Louis.

The Kellogg Foundation-financed project continues until August 1992. The project is experimental in nature. It, of course, is testing if the two organizations can effectively cooperate to the mutual benefit of their memberships. In addition, the association is challenged to appraise if these types of activities are appropriately conducted by the association and how such activities might be financed in the future.

Lyle Schertz, editor

Report of the *Newsletter* Editor

No major problems have been experienced thus far with the transition. Bruce Greenshields has been organized, cooperative, and insightful. Thanks are also expressed to Pam Patterson and Barb Fausch of the AAEA Business Office. Barb expeditiously replaced Pam as newsletter secretary after the second issue of 1990, when Pam accepted employment with the Cooperative Extension Service. Barb overcame some initial trepidation and quickly developed excellent computer skills.

We published and mailed a total of 14,500 copies of the first three issues of 1990, relative to 13,100 for the same 1989 issues. Publications costs have remained between 26¢–31¢ per copy. However, because of an increase in postage plus new clerical expenses, our deficit for 1990 to date is −$3,451 relative to −$1,971 for the same 1989 issues. If recent-year trends continue, the last three issues for 1990 will reduce this year's deficit.

The newsletter format has been changed to right-hand justification and includes "Food for Thought" quotes to minimize white space and add a bit of of intellectual content. A procedural change has been elimination of the responsibility for cross-referencing personnel changes by our production staff, a change made for two reasons: (*a*) to reduce errors, e.g., determining whether a person hired by School A was a "Resignation" or "Recent Graduate" from School B; and (*b*) to reduce the work load on our production staff. Notice of the procedural change was published twice in the newsletter and three times in the bimonthly reminder letter to department heads. The change has helped and apparently been readily accepted. I have received no complaints.

Because of sporadic problems with our current printer, e.g., improper pagination, the possibility of reducing production expenses, and our interest in improving the newsletter's physical attractiveness, we are investigating alternative printers. A draft cover page from another printer is attached.

When space permits, I will institute a new column titled, "Making Connections," aimed at sharing some of the diverse cultural and intellectual resources in our profession. Several authors have agreed to write eclectic essays of approximately 1,000 words on interdisciplinary subjects of their choice, with an economic component. Topics will not compete with papers appropriate for the *AJAE* or *CHOICES*. Lyle Schertz likes and supports this idea. All comments and suggestions are welcome.

Mike Ellerbrock, editor

Report of the AAEA Awards Committee

As outgoing chairperson of the AAEA Awards Committee, I will offer a few reflections about the award's process as I have observed it over the last three years of committee activities. The first, and most important, factor to stress is that the process of selecting awards across the several categories for which the association provides recognition operates very smoothly. A large number of nominations (in some cases including several items of documentation) are submitted each year, and they receive thorough evaluation from members of the profession. The willingness of large numbers of the association's members to devote their time and energy to this task make this process possible. The AAEA members who chair the individual award committees deserve special mention and appreciation for the considerable time, effort, and leadership they devote to the process. The AAEA is fortunate to have members who willingly give their talent to this important task. (The names of the individuals who this year served the association in these roles are listed at the end of this report.)

A second issue to recognize is that the evaluation process for each of the award areas can be difficult. The "Quality of Communication" and the "Distinguished Policy Contribution" categories, however, have an additional challenge arising because of the diversity of materials presented within those categories. Often committee members are faced with the difficult task of comparing different forms of media (for example, books vs. multimedia presentation). Also committee members often have to evaluate the intellectual effort of a group of scholars versus the contribution of a single author. These differences cause difficulty for committee members. A number of times this has led to the suggestion that group and individual awards be given in these categories. Another suggestion is to limit or further define what forms of media are appropriate for submission. Personally, I do not favor the development of further awards or

limits on media forms. Rather, it has served the association well to rely upon the professional judgment of the committee members to make these difficult choices.

A third factor occasionally raised is whether AAEA membership is a requirement for submission of an entry. Careful reading of the Awards Program instructions (Article V of the AAEA Bylaws as listed in the 1987 *AAEA Handbook and Directory*), indicates that membership is not a requirement for any award. The issue of membership is addressed only in two categories, where the wording relates to who may submit nominations, not the status of the nominee. If AAEA membership is a desired requirement for nominees to the award's program, it is my opinion that an amendment to Article V of the ByLaws is needed.

A fourth factor relates to the relatively small number of nominees for awards in some of the categories. In particular, the subcategories within the "Distinguished Extension Program" and the "Distinguished Policy Contribution" award categories have relatively small numbers. Reviewing annual reports of this committee over the last decade, I was surprised to find that publication of the number of the nominees is a relatively recent phenomena. I would urge that the information on number of nominees continue to be published each year so that association members can have better information about the likelihood of success within specific categories. A listing of the number of submissions for each award, the number of awards, and individuals receiving recognition this year is given in table 1 below.

The award-winning titles and the names of the award recipients also follow. Unfortunately, there were two errors in the Awards Ceremony brochure distributed at the annual meetings. With the "Quality of Communication" category, the editors of the USDA report, "Agricultural-Food Policy Review, U.S. Agricultural Policies in a Changing World," were incorrectly identified. In the "Outstanding Masters Thesis" category, Brett M. Gellner's first name was misspelled. I apologize for these errors and the correct citations are noted below.

It has been an honor to serve as general chair of the Awards Program this year. The assistance of President Batie and Lona Christoffers, of the AAEA Business Office, were instrumental to our successfully conducting the awards evaluation process and their assistance is greatly appreciated. In addition I would like to repeat my appreciation for the support of past Presidents Mandershield and Padberg in the two prior years I served in this capacity.

Annual Awards

Distinguished Undergraduate Teaching

Less than ten years' experience. **Dorothy A. Comer,** University of Florida.

More than ten years' experience. **Bernard L. Erven,** Ohio State University.

Distinguished Extension Programs

Individual. **Ross O. Love,** Oklahoma State University, "Intensive Financial Management and Planning Support" (IFMAPS) program.
Group. "Farm Financial Management and Planning" (FINPACK), University of Minnesota, **Richard Hawkins, Dale Nordquist, and Robert Craven.**

Distinguished Policy Contribution

Otto Doering, Purdue University, for his applied public policy research and education on energy use planning and public utility regulation in the state of Indiana.

Publication of Enduring Quality

Alan Randall, Berry C. Ives, and Clyde Eastman. "Bidding Games for Valuation of Aesthetic Environmental Improvement." *J. Environ. Econ. and Manage.*, 1974. Randall was at the University of Kentucky and Ives and Eastman were at New Mexico State University at time of article's publication.

Outstanding Journal Article

Thomas W. Hertel. "Negotiating Reductions in Agricultural Support: Implications of Technology and Factor Mobility." *Amer. J. Agr. Econ.* 71(1989):559–73.

Quality of Communication

Kenneth L. Robinson, Cornell University. *Farm and Food Policies and Their Consequences*. Englewood Cliffs NJ: Prentice-Hall, 1989.
Ivan Roberts, Graham Love, Heather Field, Nico Klijn. *U.S. Grain Policies and the World Market.* Canberra: Australian Bureau of Agricultural and Resource Economics, July 1989.
Honorable Mention. **Suchada V. Langley and Kathryn Lipton.** *Agricultural-Food Policy Review, U.S. Agricultural Policies in a Changing World.* Washington DC: U.S. Department of Agriculture, Econ. Res. Serv. Agr. Econ. Rep. No. 620, Nov. 1989.
Carol S. Kramer, ed. *The Political Economy of U.S. Agriculture, Challenges for the 1990s.* Washington DC: National Center for Food and Agricultural Policy, Resources for the Future, 1989.

Quality of Research Discovery

Robert G. Chambers, and Richard E. Just, University of Maryland. "Estimating Multioutput Technologies." *Amer. J. Agr. Econ.* 71(1989):980–95.
Jeffrey T. Lafrance, and W. Michael Hanemann, Montana State University and University of California-Berkeley, respectively. "The Dual Structure of Incomplete Demand Systems." *Amer. J. Agr. Econ.* 71(1989):262–74.

Outstanding Ph.D. Theses

Marcel Fafchamps. "Sequential Decisions Under Uncertainty and Market Failure: A Model of Household Behavior in the African Semi-arid Tropics." University of California, Berkeley (Alain De Janvry, advisor).
Richard Bergen Standiford, IV. "A Bioeconomic Model of California's Hardwood Rangelands." University of California, Davis (Richard Howitt, advisor).
Everett Bryon Peterson. "The Farm-Retail Price Spread Revisited: A General Equilibrium Perspective." Purdue University (Thomas W. Hertel, advisor).
Honorable Mention. **Satheesh V. Aradhyula.** "Policy Structure, Output Supply and Input Demand." Iowa State University (Stanley Johnson, advisor).
David Simon Kraybill. "A Computable General Equilibrium Analysis of Regional Impacts of Macroshocks in the 1980s." Virginia Polytechnic Institute and State University (Tom Johnson, advisor).
Thomas Iver Wahl. "Modeling Dynamic Adjustment in Japanese Markets Under Trade Liberalization." Iowa State University (Gary W. Williams and Dermot Hayes, advisors).
Alfons Weersink. "The Distributional Impacts of Technical Change on the U.S. Dairy Sector." Cornell University (Lauren Tauer, advisor).

Outstanding Master's Theses

Brett Miles Gellner. "An Analysis of the Demand for New Wood Panels and other Forest Products in the Canadian and United States Construction Industries." University of Alberta (Luis Constantino, advisor).
Brian Kent Engel. "Relationships Between Distributions of Price Expectations Implied by Futures and Options Markets with Distributions Elicited from Farmers and Merchandisers." University of Illinois (Robert Hauser and Sally Thompson, advisors).
Kyle Stiegert. "Price Spreads and Market Structure in the Beef Packing Industry." University of Nebraska (Azzaddine M. Azzam, advisor).
Honorable Mentions. **Hector Rodolfo Malarin.** "An Analysis of Irrigation Equipment Investment for Georgia Coastal Plain Farms." University of Georgia (Donald Reid, advisor).
James Roger Clemmons. "Economic Models of the Demand for Species Variety in Sport Hunting." University of Florida (Walter Milon, advisor).
Swati Bhargava. "A Stochastic Dominance Analysis of Broiler Growout Housing Investments." University of Delaware (Conrado M. Gempesaw, II, advisor).

Steven T. Sonka, chairperson

Report of the AAEA Foundation, 1989–90

The AAEA Foundation has completed five years of operation. Activities continued at an accelerated rate during the past year in both program and finance categories.

Program Activities

The Foundation has adopted the following priority areas of activities—*CHOICES*, Minority Professionals, Student Development, and International Travel.

AAEA fellows committee. Three years ago the AAEA Foundation took the lead in contacting AAEA Fellows for the purpose of evaluating their relationship to the association. This resulted in the establishment of a roster of fellows willing to give seminars and lectures to 1890 and similar institutions. The Foundation hosted a Fellows Breakfast at the 1989 annual meeting. Fellows were invited to express their thoughts with respect to the association and their relationship to the association. As a result of comments made at the breakfast, the Foundation president suggested to Association President Batie that a committee of fellows be appointed by the association, which has been done.

Minority travel grants. The foundation is pleased to report that seven $500 grants were made to support attendance at the Vancouver meeting.

Student travel grants. The foundation also provided fifteen student travel grants for the Vancouver meeting. The AAEA student advisor assisted in the selection of those who received grants.

Library materials and University of La Molina, Peru. The foundation provided support for sending library materials, including issues of the *AJAE*, to this University.

Appreciation clubs. The Fred Waugh Appreciation Club was recognized at a special ceremony at the USDA in the fall of 1989, when a USDA auditorium was named in his honor.

The W.E. Grimes Appreciation Club was chartered at the fall 1989 meeting of the Foundation Board. Its charter was presented at the University of British Columbia. Donations and pledges now stand at approximately $16,000.

Financial Report

Financial status. Assets of the foundation were approximately $120,000 30 June 1990. This represents a 26% increase from a year earlier. Much of this increase can be attributed to the appreciation clubs, but some has been the result of an increase in the value of the foundation investment portfolio. The foundation has a considered investment policy with a 6% spending rule.

Even though the assets of the foundation have increased significantly, they are still considerably short of our goal. An endowment in excess of $1 million is needed to fund the priority projects that have been established by the foundation.

Corporate fund raising. With leadership from Larry Boger and Gene Swackhamer, a corporate fund raising program was launched during this past year. Corporations being contacted are mainly those that have AAEA members as employees. Each member of the foundation board has an assignment to contact certain corporations on this list. Results to date have been modest, but those with experience with this type of fund raising know that patience and persistence are required.

Asset management. Two years ago the foundation adopted guidelines for the investment of foundation assets as well as a 6% spending rule. This has permitted the foundation to hold some of its assets in a form to permit greater growth and earnings. The future of the foundation is now more certain than it was at that time. As a consequence, the guidelines adopted two years ago are being reviewed in light of the current outlook for the foundation.

The foundation notes, with great appreciation, the annual support provided by the association to the foundation. Even though we have made progress in improving our capital funding, we very much hope the annual allocation can be continued. This allocation permits the foundation to tell prospective donors that most of any contribution they may make will support the foundation programs rather than be used for administrative expenses.

Members of the foundation board for 1989–90 by class: elected by AAEA membership, Lawrence Boger, John R. Brake, Emery N. Castle, Kenneth R. Farrell, Jean D. Kinsey, W. Burt Sundquist; representative from AAEA Executive Board, Walter Armbruster, Lester Manderscheid, Richard K. Perrin; appointed by board, Gene L. Swackhamer, Gary L. Seevers; ex officio, Raymond R. Beneke. Officers for 1989–90 were Emery N. Castle, president; Lawrence Boger, vice-president for finance; Jean D. Kinsey, vice-president for program.

Board members who have completed their elected or appointed terms are Emery N. Castle, Jean D. Kinsey, Lester Manderscheid, and Richard K. Perrin. Newly elected members for a three-year term are Bruce Johnston and John Lee. Officers nominated for 1990–91: Kenneth Farrell, president; Lawrence Boger, vice president for finance; Burt Sundquist, vice president for programs.

Emery N. Castle, president
AAEA Foundation Governing Board

Committee on Women in Agricultural Economics

The Board of the Committee on Women in Agricultural Economics [Joyce Allen (1988–90), Deborah Brown (vice-chair), Gene Futrell (AAEA Board Representative), Sermin Hardesty (1989–91), Joy Harwood (1989–91), Helen Jensen (past chair), Vickie McCracken (1988–90), and Eileen van Ravenswaay (chairperson)] met twice via teleconference. The CWAE chairperson appointed 12 subcommittees and 2 liaisons to carry out CWAE activities. These were published in the fall issue of the *CWAE Newsletter*.

At the request of the AAEA Board, the *CWAE Newsletter* became self-supporting this year by charging a $5.00 annual subscription fee for three issues published in the spring, summer, and fall. The fall 1989 newsletter, containing a subscription notice, was mailed free to all AAEA members. The 1990 spring issue was mailed to approximately 170 subscribers, with complimentary copies distributed free of charge to women graduate students. The summer issue will be mailed out following the 1990 annual meetings. Joy Harwood was editor and produced all three issues (Deborah Brown and Coletta Moser were subcommittee members).

Because it is costly to advertise, the CWAE Board has requested the AAEA Board to allow the *CWAE Newsletter* subscription charges to be included on the AAEA annual billing form. The AAEA Membership Committee has supported this request and forwarded it to the AAEA Board for action. The CWAE Board has also requested that the *CWAE Newsletter* be included on the omnibus subscription form sent to reference rooms and libraries.

The Graduate Student subcommittee (Hui-Shung Chang, chair; Mary Marchant and Lydia Zepeda, members) surveyed department chairs to identify a person in each department to receive and distribute complimentary copies of the *CWAE Newsletter*. These contact persons were asked to distribute the news-

letter to women graduate students and to display the newsletter in the department library, reference room, or bulletin board.

The survey was also used to collect information on women faculty and graduate students. It was found that, on average, agricultural economics departments have 1.7 women faculty members; 30% of their masters students and 21% of their Ph.D. students are women.

In order to get a larger and more diverse set of job announcements in the *CWAE Newletter*, letters were sent to potential employers by the employment subcommittee (Linda Calvin, chair; Kristin Allen, Cheryl Danley, Jill Findeis, Emily McClain, and Sermin Hardesty, members) telling them about the *CWAE Newsletter* and encouraging them to advertise there.

Notices were put in the AAEA and CWAE newsletters about the availability to potential employers of a direct mailing list of women AAEA members. This list, which includes information about AAEA members' areas of specialization, was maintained by our membership subcommittee (Helen Jensen, chair); Carole Nuckton, member) in cooperation with the AAEA Business Office (Lona Christoffers). The list currently consists of 361 women who comprise 8.8% of the members of AAEA. This number is down from 418 women a year ago.

The Elections subcommittee (Edna Loehman, chair; Catharine Halbrendt, Jean Kinsey, and Vickie McCracken, members) solicited nominations for the 1990–91 CWAE vice-chair and two board members to serve two-year terms during 1990–92. They developed a ballot with two nominations for vice-chair and four nominations for board members. The ballot was mailed by Lona Christoffers to all women AAEA members and all subscribers of the *CWAE Newsletter*, and 127 ballots were returned. The election for vice-chair was won by Joy Harwood, and the new board members are Julie Caswell and Bonnie Colby. Continuing CWAE board members are Deborah Brown (chairperson), Eileen van Ravenswaay (past chair), Sermin Hardesty (1989–91), and Joy Harwood (1989–91). There will be one less member of the CWAE Board during the 1990–91 year because Joy Harwood is both a continuing board member and the vice-chair.

The Planning subcommittee (Joyce Allen, chair; Margaret Andrews and Tanya Roberts, members) summarized results from a questionnaire distributed at last year's CWAE luncheon. This summary was used for planning this year's activities. The subcommittee published a questionnaire on career development in the fall 1989 *CWAE Newsletter*. Only twenty-five responses were received. Margaret Andrews summarized results in the spring 1990 *CWAE Newletter*.

The Professional Activities subcommittee (Stephanie Mercier, chair; Kate Buckley, Christina Gladwin, Rebecca Lent, and Ann Vandeman, members) organized two career workshops for the 1990 AAEA meetings. The workshop on career and family featured a panel of speakers from government, academia, and the private sector. The workshop on sexual harassment featured Jan Salisbury. The Farm Foundation provided $1,000 for the speaker and the Resources and Technology Division of ERS USDA provided $450 for videotaping.

The Research subcommittee (Catherine Lemieux, chair; Sandra Archibald and Patricia Duffy, members) organized a symposium for the 1990 AAEA meetings entitled "Pitfalls and Rewards of Theoretical and Applied Research: Implications for Young Professionals." Three panelists presented a variety of viewpoints. An abstract will be prepared for the December *AJAE*.

The Arrangements subcommittee (Eileen van Ravenswaay) hosted a reception and informal discussion with Donald McCloskey on "The Feminization of Economics" at the 1990 AAEA annual meetings. The subcommittee also arranged the CWAE annual luncheon, combined this year with the annual business meeting.

The Archives subcommittee (Ardell Lundeen, chair, and Sylvia Lane) maintained copies of the *CWAE Newsletter* and reports of the CWAE Board and subcommittees.

The Finance subcommittee (Valerie Vantreese) reported that there may be little need for this subcommittee. Lona Christoffers of the AAEA Business Office maintains the financial records for CWAE, and these could be reported on a regular basis to the CWAE chairperson. As of July, Lona Christoffers reported that CWAE has $2,379.46 in its accounts after covering expenses for the AAEA meetings and the *Newsletter*. This amount reflects the fact that subscription fees appear to adequately cover *CWAE Newsletter* expenses, and the Farm Foundation and the Resources and Technology Division covered the major costs for the workshops at the AAEA meetings. Consequently, the $2,000 made available by ERS through a previous cooperative agreement remain available for projects during the 1990–91 year.

Last July, Maureen Kilkenny submitted a proposal to the CWAE board suggesting the development of a scholarship fund. The board met via teleconference in September and decided to establish a subcommittee to further develop the proposal. In May, the Scholarship subcommittee (Maureen Kilkenny, chair; June Grabemeyer, Sermin Hardesty, Helen Jensen, Vicki McCracken, Tanya Roberts, Jean Sussman, and Eileen van Ravenswaay, members) submitted a draft proposal for the CWAE Board to study. The board teleconferenced in June and decided that the proposal should be submitted to CWAE members at the annual CWAE business meeting. The board also decided that if CWAE members decided to establish a CWAE scholarship, this should be done through the AAEA Foundation Board with a minimum endowment target of $33,333. The subcommittee drafted a summary proposal and a questionnaire for distribution at the annual CWAE business meeting.

Eileen van Ravenswaay, chairperson

Minutes

Minutes of the AAEA Executive Board Meeting, Orlando, Florida, 15–16 December 1989

Present: Voting Members:
Armbruster, Batie, Eidman, Futrell, Gardner, Libby, Manderscheid, Miranowski, and Perrin

Members ex officio:
Barry, Beneke

Guests:
Bollman, Carsrud, Christoffers, Howe, Johnston, Martin, Shumway, and Schertz

The meeting of the Executive Board of the American Agricultural Economics Association convened at 8:00 A.M., Friday, 15 December 1989, in the Margate Room of the Stouffers Resort Hotel in Orlando, Florida. Lester Manderscheid gave a report of the nominating committee's activities and welcomed the nominees for president-elect, Warren Johnston and William Martin, as guests for the meeting.

1. President Sandra Batie opened the meeting with introductions. MOTION: It was moved by Lester Manderscheid to accept the July 1989 Baton Rouge minutes as printed. Vernon Eidman seconded. Motion carried.

2. Batie asked for suggestions on the agenda, added several herself, and recorded additional items suggested by the board.

3. Peter Barry affirmed the association has a long-term contract with University Microfilms in Ann Arbor, Michigan, for putting the *AJAE* on microfilm and microfisch. Royalties are paid to the association on a yearly basis for sales/rentals of this material.

4. It was announced that Mike Ellerbrock from East Texas State University was appointed the new *AAEA Newsletter* editor. Mike has adjusted the deadline for submission of newsletter items to the 15th of the month preceding publication, rather than the 20th of the month.

5. Progress is being made toward the finalization of volume 4 of the Post Literature Review. Lee Martin has stated that publication should appear in the spring of 1990.

6. Support for CAST by the AAEA was discussed briefly but no action was taken by the board.

7. The special election to select a president-elect was discussed. The importance of timeliness for this project was emphasized, and a decision was made that ballots must reach the secretary-treasurer by 1 February 1990 in order to be counted.

8. Walter Armbruster announced the intention of the AAEA Foundation Governing Board to fund up to $2,000 for support of travel of minority professionals and up to $2,000 for travel for undergraduate students. Both grants are intended to support travel to the upcoming summer meeting in Vancouver.

9. Batie reported that Clifton Wharton, Jr., had agreed to give the fellows address at the Vancouver meeting.

10. John Miranowski reported that an agreement has been reached with the National Agricultural Library in Washington, DC, to house the archives of the association. After the agreement is signed, Miranowski will work with Wayne Rasmussen to develop appropriate procedures for transferring items to Washington, and for any cataloging/indexing of proposed materials. A notice will be placed in the association newsletter to inform the membership of these plans and to suggest that any member in possession of potential archive materials contact the AAEA Business Office.

11. World Food Day was discussed but no action was taken.

12. Batie reminded the board that the ASSA meeting will be held in Atlanta, Georgia, 27–30 December 1989. Because no board meeting will be held at this meeting, there will be no association compensation for board members who elect to attend. She reminded the board that the AAEA reception is to be held Wednesday evening, 27 December at 5:30 P.M. She also distributed to the board the programs for the AAEA portion of the meeting.

13. Updates from various AAEA committees were provided as follows:

Awards. Deb Thunberg, Batie's assistant, will be the official photographer for the Vancouver meeting.

Adaptive Planning. Reported elsewhere in these minutes.

Ad-Hoc Committee on Economic Education. Identified reasons for an AAEA/JCEE (Joint Council on Economic Education) affiliation, affirmed that a liaison exists between AAEA and NAEE (National Association of Economic Education) and submitted an invited paper session proposal on why and how AAEA should be involved with youth economic education.

Economic Statistics Committee. Prepared draft resolutions concerning: (*a*) standard rural statistical areas and (*b*) environmental monitoring; conducted follow-up activities to data conference.

Employment. Reported the undergraduate brochure is in final stages of revision.

Extension. Identified possible activities for inclusion in the 1990 program.

Fellows Activities. Is considering an organized symposium at the 1990 meeting.

Finance. Reported elsewhere in these minutes.

Information Retrieval. Called attention to the AERO Conference to be held in March 1990.

International. Reported on plans for the Vancouver meeting.

Professional Activities Committee. Provided suggestions for improving the annual meeting.

Professional Relations between the People's Republic of China and the United States. Reported that several subcommittees are at work on proposals for the Vancouver meeting as well as a liaison with the professional association in agricultural economics and related areas in the PRC.

Ad-Hoc Committee on the Professional Relations Between the USSR and the United States. Approved the proposal for Joint Soviet/American Committee on Agricultural Economics and the organization of sessions for the Vancouver meeting.

Resident Instruction. Proposed both an invited paper and "invited symposium" for the Vancouver meeting.

Selected Papers. Reported on selected topic leaders; announced deadline for papers as 22 February.

Selected Posters. Announced deadline for posters as 8 March.

Student Section. Reported that a representative from the University of Guelph has been added to facilitate interaction with Canadian schools for the Vancouver meeting.

14. Charlene Carsrud reported on possible rotation sites for future annual meetings. After discussion concerning places where the association has already met, the board decided that two locations which would be likely candidates to include in the rotation in the West are San Diego, California, and Reno, Nevada. The board agreed to tentatively designate the following sites in the Midwest for further study: Minneapolis, Minnesota; Kansas City, Missouri; and Columbus, Ohio. Because the association is meeting in Baltimore in 1992 and the board has now seen Orlando, the decision was made to look at Atlanta, Georgia, as a third eastern location. Canadian cities nominated for inclusion in the rotation were Vancouver, Quebec City, and Toronto. Carsrud was asked to bring information about the suggested sites to the August board meeting.

15. Carsrud reported that, after three years of negotiations with the Soil and Water Conservation Society and convention and hotel people in Baltimore, we now have the information we need to sign contracts to secure the space needed for the Baltimore 1992 meeting. There was concern that the cost of meeting in Baltimore would be high, but a group of hotels will be selected that would provide participants a reasonable assortment of hotel rates ranging from low to high. The board decided Carsrud should make the necessary arrangements to meet in Baltimore in 1992. It was suggested that the Northeastern Association also be contacted about a joint meeting in Baltimore.

16. President Batie noted that the board needed to discuss the length of the annual meeting at Vancouver. MOTION: Walter Armbruster moved to add an additional day to the 1990 annual meeting. Miranowski seconded. Motion carried. It was decided to have registration and the joint reception on Saturday, 4 August. Carsrud is to contact the Industry and International Committees to check the feasibility of holding the two banquets on different days. The opening session will start after lunch on Sunday. The president will coordinate AAEA activities with those of the other associations meeting at the same time. Conflicts on scheduling will be resolved by the president with the assistance of the business office.

17. Carsrud reported having had a conversation with Marc Johnson from Kansas State University about the 1991 meeting to be held in Manhattan, Kansas. In early September she mailed him copies of several reference materials that he might use in planning the annual meeting. Contact will be made with Johnson after January. A preliminary planning meeting will be scheduled as soon as a new president-elect has been elected.

18. President Batie asked for a report on the Baton Rouge meeting. Carsrud pointed out that a complete accounting of expenses accrued at the meeting has not yet been received from Louisiana State University but is expected shortly. Batie requested that a copy of the final analysis of the budget be faxed to her as soon as it is complete and expressed a desire to have board members informed concerning the financial outcome of the 1989 meeting.

19. The board decided to use the *AAEA Newsletter* for an item explaining to members why the annual meeting registration fee is $70.00. MOTION: Richard Perrin moved that the annual meeting registration fee for those with a senior membership be reduced to one-half of the regular fee. Gene Futrell seconded. Motion carried.

The board adjourned for supper at 7:30 P.M. to reconvene at 8:30 P.M. for the purpose of Fellows selection.

20. Miranowski led the board through the Fellows selection process and reviewed the guidance provided in the constitution and by-laws on criteria for selection and the procedures followed in past years. After several rounds of sequential balloting, nine names emerged to be forwarded to the Fellows Selection Committee.

The Board adjourned at 10:45 P.M.

The Board reconvened at 8:00 A.M., 16 December 1989, with additional business items.

21. Futrell presented a proposal from the Extension Committee for a one-day pre-conference "Challenges For Extension Education in the 1990s." MOTION: Manderscheid moved to approve the preconference. Armbruster seconded. Motion carried.

The Extension Committee recommended the continuation of the commodity outlook session as a regular part of the annual meeting. MOTION: Armbruster moved to approve the recommendation. Futrell seconded. Motion carried.

The Extension Committee recommended the addition of a policy session which would complement

the outlook session at the Vancouver meeting. This proposal was not approved; however, it may be resubmitted as an organized symposium.

22. Two proposals for learning workshops presented by the Professional Activities Committee were discussed. Lawrence Libby will contact Paul Barkley of the PAC to develop one of the proposals and to coordinate the details with President Batie. The workshop would be blended in the regular program. MOTION: Manderscheid moved that a learning workshop be approved. Eidman seconded. Motion carried.

23. Ray Bollman, president of the Canadian Agricultural Economics and Farm Management Society, presented a proposal for a joint AAEA/CAEFMS preconference on "Agriculture and Rural Restructuring." This program parallels a proposed symposium planned by the community network group. MOTION: Armbruster moved to accept the Canadian proposal and for Bollman to coordinate with the community network group to reach an agreement. Manderscheid seconded. Motion carried.

24. Two program proposals from the Committee On Women in Agricultural Economics were discussed. These proposals, based on the topics of "Career and Family" and "Sexual Harassment" will be blended into the regular program format at the Vancouver meeting. MOTION: John Miranowski moved to approve these workshops. Libby seconded. Motion carried.

25. A proposal from the Resident Instruction Committee on "Critical Issues in Graduate Agricultural Economics Education" was discussed. This proposal uses an "invited symposium" format in order to provide a forum for discussion from the floor. The presentations will not be automatically published in the *AJAE*, but presenters are invited to submit their papers through normal procedures. MOTION: Futrell moved to approve this proposal as a committee sponsored symposium. Eidman seconded. Motion carried. Futrell is to inquire as to the feasibility of video taping this program.

26. Richard Shumway, president of the Western Agricultural Economics Association, presented the paper sessions being planned by his group. These sessions are primarily method oriented. WAEA will strive to avoid times that conflict with other sessions. Shumway also proposed having a joint awards program.

27. Richard Perrin, chair of the Finance committee, reported that the revision of the financial statements for the association and the foundation are being designed to give more complete and concise information about our financial status. These forms will be ready by the August meeting.

Perrin reported that the AAEA Foundation had responded negatively to the proposal that financial and supervisory oversight for *CHOICES* activities be delegated to them. Oversight for activities will remain as they are now, with the three presidents.

28. Proposed changes to the bylaws reported by Manderscheid, regarding the president-elect and the newsletter editor, were tabled until the August meeting.

29. Bruce Gardner led a discussion of invited paper proposals for the Vancouver meeting. The topics agreed upon and the persons who could function in each case as an organizer are as follows:

Resource Economics
(1) Douglas Southgate (AERE)—Resource Degradation in Third World (C. Howe)
(2) Canadian No. 8—Sustainable Development (Bollman)
(3) Charles Howe (AERE)—Agriculture-to-Urban Water Transfer (Bollman)

Rural Development
(4) Ralph Christy—Rural Development and Disadvantaged Groups (Libby)

Demand and Marketing
(5) Richard Shumway (WAEA)—Demand Analysis Issues (Shumway)
(6) Wayne Purcell—Livestock Concentration (Armbruster)

Cost, Technology and Investment
(7) Mary Ahearn—International Cost Comparisons (Miranowski/Bollman)

International Development
(8) Gershon Feder—Agricultural Credit (Perrin)
(9) Truman Phillips—Food Insecurity (Manderscheid)
(10) Vincent Cusumano (International Committee)—Aid and Structural Adjustment in Third World and Eastern Europe (Armbruster)

International Trade
(11) P. Lindsey—United States/Canada Free Trade Agreement (Bollman)
(12) Canadian No. 3—Pacific Rim (Bollman/Futrell)

Agriculture Policy
(13) Canadian No. 2—Stabilization Policy (Bollman)
(14) Canadian No. 9—Political Economy of Canada (Bollman)

Economic Education
(15) Kim Reda-Wilson—Youth Economics Education (Batie)
(16) Richard Shumway (WAEA)—Applied Welfare (Shumway)

Batie set a deadline of 31 January for submission of definite plans for each session.

30. Lyle Schertz, editor of *CHOICES* Magazine, gave a review of *CHOICES* activities for 1989, as well as an overview of the Kellogg Project. One press conference has been held in connection with the fourth quarter 1989 issue of *CHOICES*. More then twenty press people were present. Future plans for *CHOICES* include: (*a*) a press conference tentatively planned to focus on each of the 1990 issues, (*b*) identification of a person to take on the subscription promotion responsibilities, and possibly the advertising responsibility, (*c*) Schertz also called the board's attention to the memorandum of understanding between the as-

sociation and Lyle Schertz, which provides for adjustment in compensation for Schertz consistent with the percentage change in salary schedule for GM-15 employees of the U.S. government. Under this arrangement Schertz indicated his 1990 salary would be $44,030.00. He also recommended that the board approve the expenditure of approximately $8,000 for the purchase of a McIntosh computer and printer which would facilitate magazine preparation. MOTION: Miranowski moved the association authorize the purchase of an Apple McIntosh computer for *CHOICES*. Libby seconded. Motion carried.

Schertz discussed with the board the need for an associate editor to insure the long-term survival of *CHOICES*, help with the technical part of the preparation activities and to take over subscription promotion activities. This person is not to be an editor but would be a part-time employee with Schertz as overseer. MOTION: Miranowski moved to ask Schertz, with the help of the President's Council, to prepare a position description for an associate editor with a $40,000 limit on expenditures. Armbruster seconded. Motion carried.

31. Otto Doering, chair of the Adaptive Planning Committee reported on that committee's progress. Such questions as "Where is agricultural economics headed? How is the association viewed by the members? What is and should be the central core of the association's functions?" have been addressed. Areas for potential growth opportunities of the association were explored. These included the unbundling of publications and altering the structure of the association to encourage more participation by "federated" groups. MOTION: Manderscheid moved the board approve the distribution of a preliminary report by the Doering committee before the Vancouver meeting and the scheduling of a symposium at Vancouver with a revised report distributed as soon as possible after the close of the summer meeting. Perrin seconded. Motion carried.

32. Peter Barry reported that Julian Alston had replaced Bruce Gardner on the Board of Associate Editors for the *AJAE*. Barry discussed the storage policy being used for back issues of the *Journal* by Edwards Brothers. The recommendation to include the proceedings of the winter meeting in the August issue rather than the May issue was approved. Miranowski led a discussion regarding a notation on the release of restrictive data if cited in articles in the *Journal*.

33. Raymond Beneke presented a partial list of awards available to agricultural economists or economists but concluded that, historically, appropriate candidates had been nominated by other organizations.

34. Futrell reported on the AAEA affiliation with the Consortium of Social Science Associations (COSSA), and recommended that AAEA make a strong effort to utilize that affiliation in support of broad research thrusts of particular importance to agricultural economists. MOTION: Armbruster moved that we continue our COSSA affiliation at a cost of $2,000 for 1990 and a liaison be appointed from an AAEA Committee. Futrell seconded. Motion carried.

MOTION: Armbruster moved that the president establish an AAEA committee to develop a strategy and plan to enhance the involvement of the AAEA in initiatives related to the rural social sciences. Libby seconded. Motion carried.

35. A letter from the chair of the Council of Professional Associations on Federal Statistics (COPAFS) was circulated. After discussion, Batie indicated she would confer with Leroy Hushak (AAEA's representative to COPAFS) regarding the benefits of the association affiliation with COPAFS. MOTION: Manderscheid moved to approve the COPAFS request for a $6,930 contribution for 1990. Miranowski seconded. Motion carried.

36. Batie reported on a request by the Economics Statistics Committee to use surplus preconference funds. The business office reported that not all preconference bills have been paid, and the financial outcome of the venture is not now known. It was agreed that surplus funds do not revert to the sponsoring committee. Several members suggested to President Batie that she invite the committee to make additional requests of the board if they had special, high priority needs for funds.

37. The following by-law changes were proposed: Article V, introductory paragraph and Section 5, second paragraph should read as follows:

Introduction to Article V: Insert the following as a complete second paragraph preceding Section 1.

> Each award program is administered by a subcommittee. The chairperson of each subcommittee is expected to organize the evaluation process to ensure that subcommittee members do not directly evaluate entries in which the members are potential award recipients or, for the theses awards, in which members have served as major advisor of a potential award winner. Subcommittee chairpersons are ineligible for an award from the program category they are administering.

Section 5, Second Paragraph:

> If an article is selected to receive both the Outstanding Journal Article award and the Quality of Research Discovery or Quality of Communication award, the matter shall be resolved by the chair of the Awards Committee in consultation with the recipient or recipients involved in such a way that only one award is received.

MOTION: Manderscheid moved we approve these changes. Perrin seconded. Motion carried.

38. The following by-law change was proposed: Article V, Section 5, Item C:

> The editor and associate editors of the *American Journal of Agricultural Economics*, with the editor as chair, shall choose an outstanding article in the volume published preceding the year of recognition.

> *All articles are automatically eligible for consideration except (i) those nominated for other AAEA published research awards with the approval of the author(s); (ii) the President's address; and (iii) the Fellow's lecture.*

MOTION: Perrin moved we approve this change. Armbruster seconded. Motion carried.

39. There was discussion about a proposal that a Joint Soviet/American Committee on Agricultural Economics be formed to facilitate interaction with Soviet colleagues. MOTION: Manderscheid moved to approve the Joint Soviet/American Committee proposals contingent on development of financial arrangements satisfactory to the board. Miranowski seconded. Motion carried.

40. The following resolution from the AAEA Economic Statistics Committee was presented:

WHEREAS there is a large and increasing demand for small area data as revealed by the Survey on Priorities for Data on Agriculture and Rural Areas and other sources, and

WHEREAS this increasing demand for data is brought about by the growing concern about a wide array of issues concerning rural viability, and

WHEREAS many data items available for urban counties cannot be published for rural counties because of disclosure rules, and

WHEREAS there exists a set of defined urban areas called Metropolitan Statistical Areas (MSAs), and

WHEREAS the MSA concept is transferable to rural counties.

BE IT RESOLVED THAT appropriate federal statistical agencies be given the responsibility and the financial resources to define Rural Statistical Areas (RSAs), which are groups of counties similar in concept to MSAs, covering rural counties of the United States. Each RSA should encompass in so far as possible an economic trading area, be small enough to be of use in local analysis and planning, and yet be of sufficient size that data can be compiled for the RSA without disclosure violations. MOTION: Manderscheid moved we approve this resolution. Eidman seconded. Motion carried.

41. The following resolution from the AAEA Economic Statistics Committee was presented:

WHEREAS there is a large and growing concern about the lack of systematic monitoring of key aspects of the natural environment as revealed by the Survey on Priorities for Data on Agriculture and Rural Areas and other sources, and

WHEREAS this is a result of increasing public awareness of the importance of environmental quality and natural resources as evidenced by regulations of ground and surface water quality from a variety of point and nonpoint sources of pollution.

BE IT RESOLVED THAT appropriate federal statistical agencies be given the responsibility and the financial resources to establish an ongoing and coordinated system of key indicators of environmental quality and the natural resource base. MOTION: Manderscheid moved we approve this resolution. Eidman seconded. Motion carried.

42. A discussion ensued regarding the format used for organized symposia, with possible redesign to be initiated at the Vancouver meeting. The Professional Activities Committee recommends that the board work closely with the selection committee to establish guidelines to enhance the quality of the organized symposia at the Vancouver meeting. PAC will evaluate the symposium program as part of an overall evaluation of the summer meeting.

43. A proposal from the Student Section–AAEA requesting additional funding support for student activities was discussed. MOTION: Manderscheid moved that the association support the SS–AAEA with a $1,500 allocation to be used as they see fit. Libby seconded. Motion carried.

44. A joint proposal from Kimberly Reda-Wilson and Lyle Schertz to fund travel of the two of them to the New York offices of the Joint Council on Economic Education to learn about JCEE activities was discussed. MOTION: Armbruster moved to instruct Schertz to use the *CHOICES* budget to fund this travel. Miranowski seconded. Motion carried.

45. Batie read a proposal from the Committee on Youth Education on Agricultural Economics. This proposal will be referred to the AAEA Foundation for possible action.

46. Futrell presented a request by the Extension Committee to conduct a direct mailing of materials to extension members encouraging participation in extension activities at Vancouver. The board approved this request and suggested the total cost not exceed $500.00.

47. A discussion of overhead on grants/contracts resulted in the recommendation that all interest accrued on accounts being held by the association be credited to the association treasury and not earmarked for individual projects.

Perrin presented to the board the following declaration of policy related to the general fund:

> All gains and losses from financial assets (interest, dividends, and capital gains from all cash and portfolio assets except those of the AAEA Foundation) will accrue to the General Fund. Accounts for special projects and organizing committees will neither accrue interest nor otherwise share in gains and losses from the association's financial assets.

MOTION: Perrin moved we adopt this policy. Miranowski seconded. Motion carried.

48. Futrell commented on the Extension Predictor's Award offered by Merrill Lynch. He suggested that the AAEA Committee should be involved in determining the criteria for selection.

49. Beneke proposed a plan to edit and reproduce the video tapes prepared for the 75th anniversary of the association into a usable and marketable item. The board suggested that this plan needed additional study and should be brought before the board in a more mature stage of development.

50. Beneke presented a packet of materials from Goodwill People-To-People Travel Program discussing the possibility of the AAEA offering its members a foreign study/travel program. Several questions concerning the association's liability and related difficulties arose and the issue died for lack of support.

51. A report from the Employment Service regarding their work on revising the recruiting brochure was discussed. MOTION: Eidman moved we support this activity up to $2,600. Manderscheid seconded. Motion carried.

52. The following change to Article IV, Section 3. of the By-laws was proposed:

> Any member of the association may nominate any living member for the honor of election as Fellow by submitting the name to the secretary-treasurer of the association not later than *1 November* or an earlier date if so announced in the *American Journal of Agricultural Economics* or any other communication to the membership.

MOTION: Manderscheid moved we accept this proposal. Miranowski seconded. Motion carried.

The meeting adjourned at 8:00 P.M., 15 December 1989.

Respectfully submitted,
Raymond R. Beneke
Secretary-Treasurer

Minutes of the AAEA Executive Board Meeting, University of British Columbia, Vancouver, B.C., Canada, 3–4 August 1990

Present: Voting members:
Armbruster, Batie, Eidman, Futrell, Johnston, Libby, Manderscheid, Miranowski, and Perrin

Members ex officio:
Barry, Beneke

Guests:
Beattie, Carsrud, Christoffers, Deaton, M. Johnson, Reichelderfer, Veeman, Willis and committee chairs, editors, and representatives as reported in the minutes

The meeting of the Executive Board of the American Agricultural Economics Association convened at 8:07 a.m. in the Faculty Club at the University of British Columbia in Vancouver on Friday, 3 August 1990. The first order of business was a review of the agenda by those members present. Several items were added to the agenda. The minutes of the December 1989 meeting were approved as corrected. President Sandra Batie welcomed the newly elected members of the board, president-elect Bruce R. Beattie and directors Brady J. Deaton and Katherine H. Reichelderfer. Batie announced the new members on the AAEA Foundation Governing Board are Bruce F. Johnson and John E. Lee, Jr. Batie introduced Michelle Veeman, president-elect of the CAEFMS.

1. Appointments for special awards committees, particularly the world food prize, were discussed. Warren Johnston will talk to R. Jim Hildreth regarding a nomination for this award.

2. During a discussion led by Walter Armbruster regarding grants for travel to the International Association of Agricultural Economists conference to be held in Tokyo in 1991, he announced the availability of approximately eight $1,500 travel grants. The AAEA Foundation will be asked to consider providing funding for two or more grants to supplement those that will be available through the association.

3. Batie announced that Council of Social Science Associations on Federal Statistics had asked for and had been provided a $2,000 dues payment for AAEA for 1990.

4. Batie discussed the International Agribusiness Association and its relationship to the AAEA. The consensus among board members was that the AAEA should offer to cooperate with the new association in any way that might be useful, including, but not limited to, joint meetings on occasion as well as working together in publicizing, promoting and distributing journals published by both organizations.

5. Batie announced that the Northeastern Agricultural and Resource Economics Association will plan to meet jointly with the AAEA in Baltimore in 1992, along with the Soil and Water Conservation Society. Batie also indicated that the Rural Sociology Society is interested in the possibility of joint meetings in 1993.

6. Peter Barry reported on the AJAE operations for 1989–90. He indicated that during the past year the *Journal* had effected a transition in printing from Heffernan Press to Edwards Brothers in Ann Arbor, Michigan. Editor Barry indicated that it appears that AAEA members and subscribers will benefit from improved timeliness in publication of the *Journal* and also from lower publication costs. Barry indicated that new submissions of manuscripts in the most recent twelve-month period (1 July 1989 to 30 June 1990) totaled 370 manuscripts, equaling the record high of two years ago. According to Barry, the mix of published articles reflects the mix of submitted material, with the dominance of research-oriented articles following through from submission to publication. Editor Barry stated that the editor's office has continued to emphasize timeliness in the handling of manuscripts. He indicated that during the past year the response times on original submissions averaged 70 days, with the response on 77% of these occurring within a 90-day period; 93% within a 120-day period; and 99% within 150 days. The publication rate was 29% of the manuscripts submitted during the year.

Barry reported that other special activities of the editor during the past year included (*a*) the development of guidelines for data availability and documentation of research procedures that now is published as item 5 on the inside of the back cover of the *Journal,* (*b*) the development of a storage policy

for back issues of the *Journal,* and (*c*) revisions in the eligibility requirements for participation in the Outstanding *AJAE* Article Award. MOTION: After an evaluation by Barry, John Miranowski moved to adopt a policy to increase the range of selected articles to 110–120 articles per year in order to reduce the waiting period for publication, at an additional cost of approximately $5,000. Richard Perrin seconded. Motion carried.

7. Perrin gave a preliminary report of the Finance Committee in which he emphasized the operating expenses of the association had exceeded operating revenue in 1989 and that the discrepancy would be still greater in 1990 and 1991. He emphasized that the association had no deficit in 1989 because of the revenue we had received in gains on sale of stock during 1989. The discussion then ensued as to what policy the board ought to pursue in placing a ceiling, if any, on the amount of resources to be accumulated in our portfolio. The matter of raising dues also came up for discussion. Batie suggested that we postpone consideration of these items until it became clear what our budget needs would be in 1991.

8. Mike Ellerbrock reported on the operation of the *AAEA Newsletter*. He indicated that the transition from Bruce Greenshields as editor to Ellerbrock had been made with a minimum of disruption. Ellerbrock reported that the association had published and mailed a total of 14,500 copies of the first three issues of 1990. He indicated that publication costs will remain somewhere between 26¢ and 31¢ per copy; however, because of an increase in postage and clerical expenses, the editor expects the *Newsletter* to operate at a deficit in 1990. The *Newsletter* format has been changed to a right-hand justification and now includes "Food for Thought" quotes, which serve to minimize the amount of white space in the publication. He also indicates that he intends to institute a new column entitled "Making Connections" aimed at sharing some of the diverse cultural and intellectual resources of the profession. Armbruster suggested that highlights of committee reports should appear in the *Newsletter*. Perrin asked Ellerbrock for a comparison of employment advertisements between the *AAEA Newsletter* and the *CWAE Newsletter*.

9. Batie directed the attention of the board to a letter which she had received from Paul Weller, executive director of the American Agricultural Editors Association. In the letter Weller argued that the editors' association ought to share in the interest earned on the Kellogg Project since this was a joint effort of the two associations. Members of the board indicated that the association had a policy of several years' standing that project committees within the association do not share in any interest that might accrue from funds which the committee, for one reason or another, has accumulated. Batie will talk to Lyle Schertz about the matter and will also write to Weller explaining our policy.

10. Warren Johnston indicated that he had appointed a search committee for the *AJAE* editorship starting in 1991. He indicated that Vern Eidman and Larry Libby would be serving on the committee and that anyone who had any suggestions should contact the committee.

11. Manderscheid introduced the matter of a single candidacy in subsequent presidential elections. Batie indicated there had been a significant volume of communication on this subject. These communications had reflected strong feelings on both sides of the issue. A thorough discussion of the pros and cons of the issue ensued. Manderscheid indicated that the present policy of choosing two candidates, both with superior qualities, had been followed for many years. No action was taken to change the present practice.

The meeting adjourned shortly after 12:00 and reconvened at 1:20 p.m.

12. Batie raised questions on several matters of budget policy. MOTION: Miranowski moved that the board adopt a rule that in lieu of gains on sale of stock or losses, the board budget 3% of the value of the portfolio for support of activities of the association. Seconded by Manderscheid. Motion carried. There was further discussion of instituting a cap on the total amount of funds which the board would permit to accumulate in the investment portfolio. This issue was not resolved.

13. MOTION: Perrin moved that the dues for regular members be increased from $45.00 to $60.00 and that dues for other categories of membership be increased proportional to the increase in regular member dues. Johnston seconded. Motion passed.

14. Lyle Schertz announced that a contract was being negotiated between the association and p.s. Express as assistant to the editor for *CHOICES*. This contract should be in place by 1 September 1990. Schertz reported on the operation of *CHOICES*. He called the board's attention to the fact that with the fourth issue of *CHOICES* in 1990 the association will have completed five years of publication of this magazine. He indicated that he had been considering ways in which the association could commemorate having achieved this milestone. Ideas which he advanced as possibilities included an extra edition of *CHOICES* in 1991 or a special issue which included extra pages. He also suggested that the association might sponsor an essay contest in which the contributions deemed most creative would be awarded a prize. The most outstanding contributions might be published in the special edition of *CHOICES* Magazine. No action was taken on any of these suggestions. The editor was asked to update the board on his current thinking on a commemorative issue at the November meeting and include a budget for the project.

Editor Schertz also discussed the possibility of placing on CD-ROM the copy from all issues of *CHOICES* that had thus far been published. In this format materials contained in all issues of *CHOICES* to date could be readily searched at a very low cost. Schertz indicated that the best estimate he could provide at this stage of the cost of this project would approximate $10,000. The board indicated this suggestion needs further exploration.

Schertz also reported upon the project he has un-

dertaken in cooperation with the American Agricultural Editors Association to better communicate America's farm policy issues to the public. This effort is being supported by a grant from the Kellogg Foundation. Schertz indicated that eleven press releases based on articles in three issues of *CHOICES* had been prepared, and that there had been three press conferences held at the National Press Club in Washington, D.C. Each set of press releases had been sent to approximately 800 people involved in the food and agricultural press. Schertz also indicated that one press backgrounder had been held in St. Louis in April 1990. The focus of this activity was the development of a better understanding of the evolution of food, farm, and resource policy from the mid-1850s to the present. This backgrounder plus one press conference have been placed on video tape. All three press conferences were audiotaped. Schertz indicated that more effort would be given in the upcoming year to preparation of video materials for distribution to the press.

Schertz reported on the meeting of the Joint Council on Economic Education that he and Kim Reda-Wilson attended in New York. The purpose of the meeting was to explore the advisability of AAEA developing a working relationship with the JCEE, and to glean information useful in preparing a proposal that AAEA undertake to rework materials that appear in *CHOICES* for use in secondary schools.

15. Perrin reported on the problems that North Carolina had encountered in attempting to work out plans to accommodate the 1993 summer meeting. The group at North Carolina State charged with making arrangements concluded that adequate facilities in Raleigh, N.C. were not available for such a meeting. They explored the Winston-Salem area as an alternative and concluded that although this would not be an ideal location, it would be preferable to Raleigh. The board decided not to make a decision on the 1993 location at this time but to give more consideration to the problem at the November meeting. Charlene Carsrud was instructed to provide the board with more detailed information on Winston-Salem as well as Orlando and any other sites she may deem feasible. This information is to be presented at the November board meeting.

16. Marc Johnson, from Kansas State University, reported that plans are going forward for the 1991 meeting. He indicated there are other activities taking place on the Kansas State campus which may provide competition for preconferences. Johnson reported that, otherwise, plans for the meeting were progressing well and that the staff at Kansas State was looking forward to showing members of the association what Kansas had to offer.

17. Miranowski reported on a workshop presented by the Institute of Food Technologists held 26–27 February 1990, in Washington, D.C., on "Achieving the Full Potential of Integrated Pest Management." The IFT is asking the AAEA to place its name on the list of professional societies endorsing this workshop report. Miranowski explained why the association should not endorse this report.

18. Wen Chern reported for the China Committee. He said that the committee was again sponsoring a symposium dealing with agricultural trade which would be a part of the 1990 AAEA annual meeting. Professor Chern indicated that Francis Tuan and Peter Calkins had been editing the proceedings of the Conference on Chinese Rural Development that was held in connection with the Baton Rouge Meeting in 1989. According to Chern, the Chinese committee is making arrangements to cosponsor a conference to be held in Beijing in 1992. Chern asked for board approval to undertake this project in Beijing. Manderscheid cautioned the committee to be very careful about using the AAEA name and asked the committee to keep their board representative informed as to progress. The project was supported in principle, but the committee was asked for more specifics on details and to keep in close touch with the president.

The board adjourned at approximately 5:30 P.M. to reconvene again at 8:00 A.M. on Saturday morning.

Batie called the meeting to order at 8:03 A.M. on Saturday, 4 August.

19. Mary Ahearn appeared on behalf of the Economic Statistics Committee and indicated that the committee was publishing the proceedings of the data conference which it sponsored in 1989. Ahearn also indicated that the committee had taken the initiative in organizing a symposium on data confidentiality to be held at the 1990 summer meetings. She indicated that the committee is planning a conference on Economic Accounting of Commodity Cost and Returns to be held on 20–22 February 1991. Ahearn reported that their 1989 preconference had created a surplus of several thousand dollars in the AAEA accounts. She requested that the board allocate $3,000 of this amount to support travel of four or five young professionals to the February 1991 conference on Economic Accounting of Commodity Costs and Returns.

Ahearn also reported for the National Agricultural Statistics Service. She indicated that, although hiring had been curtailed throughout the fiscal year as a result of budget constraints, the agency is proceeding to collect data on chemical applications as a first stage in providing estimates for the USDA Water Quality Initiative. The agency is also preparing for an important role in providing data in support of the USDA Food Safety Initiative.

20. Michael Mazzocco reported for the Selected Papers Committee, that 685 papers were received and reviewed by 231 reviewers, with 334 accepted. These papers were combined with 35 accepted papers from the CAEFMS.

The committee recommends that the early submission date for papers be continued. The submission form should be included in the November-December issue and the January-February issue of the *AAEA Newsletter* along with the "Call for Papers" in both issues. The committee recommends the revising of the number of topic areas and broadening the scope of the remainder. It also recommends a limit be placed on the number of submissions with which an individual may be affiliated, perhaps three to four. The

board suggested that the committee proceed slowly toward changing the rules. Mazzocco and Tom Knight are to write a new call for papers and a call for reviewers.

The committee also suggested an allocation of $2,500–$3,000 to the institution in support of the Selected Papers Committee to offset expenses to the department (telephone, postage, supplies, and student workers).

21. Paul Barkley appeared before the board representing the Professional Activities Committee. The one-half day learning workshop on nonmarket valuation techniques held at the 1990 meeting was a tremendous success with over 250 registrants. PAC will ask to organize two or three such workshops for the 1991 meeting. Barkley suggested that any excess revenues from the 1990 meeting be held in reserve for future learning workshops. Batie informed him of the existing policy not to do this, but the board would consider new requests for funds for future learning workshops.

The PAC distributed a questionnaire at the Vancouver meeting for the purpose of evaluating the meeting. Josef Broder (University of Georgia) is coordinating this effort.

22. The following amendments to the AAEA Bylaws regarding the awards program were presented:

> The addition of the following paragraph to the introductory section of Article V and suggest that it become the second paragraph: "Award nominees must be members of the AAEA. In the case of multiple authorship or of a group nomination at least one person must be a member of AAEA. The membership requirement is waived in the case of the Outstanding Master's Thesis Award."

MOTION: Manderscheid moved we adopt this bylaw change. Vernon Eidman seconded. Motion failed.

> Delete Section 8 of Article V. This section reads: "Section 8. Undergraduate Recipient. The Association shall provide one ticket to the official awards banquet or similar event at no charge for each undergraduate recipient of an Association award provided the recipient is present and in attendance at the awards ceremony."

This section appears unnecessary in view of the current award program format. MOTION: Manderscheid moved we adopt this by-law change. Perrin seconded. Motion carried.

MOTION: Walter Armbruster moved that the bylaws be rewritten without reference to gender and to make all reference to *AJAE* spelled out to read *American Journal of Agricultural Economics*. Miranowski seconded. Motion carried.

23. The following amendments to the constitution were presented: (changes are underlined)

> Article VI. Officers. Change Section 2 to read:
>
> "Section 2. Appointed. The executive board shall appoint a Secretary-Treasurer, an editor of the American Journal of Agricultural Economics, *an editor of Choices and an editor of the AAEA Newsletter*, all of whom shall serve for one-year terms and may succeed themselves in office."
>
> Article V. Executive Board. Change Section 1 to read:
>
> "Section 1. How Constituted. The Secretary-Treasurer, the editor of the American Journal of Agricultural Economics, *the editor of Choices*, and, upon designation by the executive board, the Presidents (or designees) of any national or regional Associations, shall be members ex officio (nonvoting) of the executive board."

These changes will be voted upon at the Annual Business Meeting.

24. The following amendments to the bylaws were presented: Article VI. Duties of Officers. Change Section 4 to read: "Section 4. Appointments. As an operating procedure, the executive board may reach agreements with appointees to the position of Secretary-Treasurer, editor of the American Journal of Agricultural Economics, *editor of CHOICES and editor of the AAEA Newsletter* for appointments of three to five years with the provision of an evaluation preceding reappointment each year and a performance review at the end of the three- to five-year appointment if an additional three- to five-year term is being considered. However, nothing in the agreement between the executive board and a candidate for either position shall be deemed to create a contractual obligation beyond that specified in the Constitution of the Association." MOTION: Manderscheid moved we adopt this by-law change. Miranowski seconded. Motion carried.

> Article XV. Editorial Advisory Board for *Choices*. Change title to: "*Choices*." Add new Sections 1 and 2:
>
> "Section 1. Role of executive board. The executive board shall:
>
> a) Elect the editor of *Choices*.
> b) Approve the criteria used in selecting other staff.
> c) Determine long-run policies affecting *Choices*.
> d) Determine the annual budget for editorial operations and printing of *Choices*.
>
> Section 2. Role of the *Choices* editor. The editor shall:
>
> a) Select the other members of the editorial staff and assistants.
> b) Determine the content of each regular issue of *Choices*.
> c) Determine the format of *Choices*.
> d) Determine operational policies for the position.
> e) Attend each regular meeting of the executive board, with travel costs paid by the Association, subject to provisions that apply to staff members of the AAEA Business Office.
> f) Be responsible for matters related to the printing of *Choices*, including serving as the major contact person with the *Choices* printer and as the

> principal advisor to the executive board on decisions in *Choices* printing.
>
> Section 3. Editorial Advisory Board for *Choices*. Members of the Editorial Advisory Board shall be appointed by the president-elect upon the recommendation of the editor of *Choices*. This advisory board will have standing committee status, with members appointed for three-year staggered terms or other lengths of appointment as prescribed by the executive board of the Association."

Manderscheid moved we adopt this by-law change. Futrell seconded. Motion carried.

> "Article XVI. *AAEA Newsletter*." (A new article).
>
> "The editor of the *AAEA Newsletter* shall be appointed by the executive board from nominations submitted by the President. The Board shall approve the general content, establish long-run policies and determine the annual budget for the *AAEA Newsletter*. The editor will be responsible for determining the content of each regular issue, and be responsible for printing and other operational policies."
>
> Renumber former Articles XVI. and XVII. as Articles XVII. and XVIII.

Manderscheid moved we adopt this by-law change. Miranowski seconded. Motion carried.

25. Armbruster reported on the National Agribusiness Education Commission report *Agribusiness Education in Transition: Strategies for Change*. A follow-up project, based on encouragement by the USDA Office of Higher Education, will assist in implementing recommendations. The project, "Strengthening Agribusiness Programs, Phase II," will bring together agriculture and business educators with human resource professionals from food and agriculture industries to design a plan for implementation. Steve Sonka, University of Illinois, will represent the AAEA on the steering committee for the project.

26. John E. Lee, Jr. of ERS USDA appeared before the board. Lee discussed the electronic database that the ERS is creating. He indicated that the service operates under the same confidentiality requirements as does the National Agricultural Statistics Service. Lee said it is a policy of the ERS to make data as widely accessible as possible, and a system is being developed to assure maximum legal access to data generated by new pesticide surveys. Lee indicated that the ERS next year would be celebrating its 30-year anniversary.

Lee presented a proposal regarding the Frederick V. Waugh Memorial Lecture Series. This lecture series would be an annual lecture, beginning with a special plenary session at the 1991 annual meeting. Nominations for speakers will be solicited through various media with a nominating committee making the final selection. Motion: Perrin moved to accept the proposal. Futrell seconded. Motion carried.

27. Otto Doering spoke to the board regarding CARAFE (Coalition for Advancement of Research on Agriculture, Food, and Environment). They have asked the AAEA on several occasions to join with them. The board will discuss this again at the fall meeting to decide whether we want representation and to make a contribution to this effort.

28. Doering spoke for the Adaptive Planning Committee. Their report was presented to the membership via the July-August *AAEA Newsletter*. The feeling has been that the membership is interested in broadening the interest base of the association. The committee suggested the board attend the symposium at the Vancouver meeting designed to discuss the report and to get feed-back from people as to the feeling on the broad issues. The report will be discussed in greater detail at the fall meeting.

29. The board then went into executive session to consider the reappointment of the secretary-treasurer. The secretary-treasurer was reappointed for the next year.

The board adjourned at approximately 12:00 to reconvene again at 1:30 p.m.

30. Charlene Carsrud of the business office reported that the final tally from the Baton Rouge meeting in 1989 had indicated a total of 1,453 participants registered for the meeting. This resulted in a net profit of $2,438.

31. Carsrud also reported that it appeared as if attendance at the Vancouver meeting would be one of record-breaking numbers. As of 30 July, 2,146 had registered, with a record number of spouses, guests, and children attending.

32. Emery Castle, president of the AAEA Foundation, appeared before the board with his 1989–90 report. Castle reported that foundation activities continued at an accelerated rate during the past year in both program and finance categories. The foundation supported the minority travel grant project with eight $500 awards to attend the Vancouver meeting. The foundation also provided student travel grants for a total of $1,600 for undergraduate travel to Vancouver. Castle encouraged the association to continue with their generous support which helps permit the foundation to tell prospective donors that most of any contribution they make will support the foundation programs rather than be used for administrative expenses. Castle also announced that the foundation board may wish to increase the number of appointed members that sit on their board in the future.

33. Raymond Beneke, secretary-treasurer, reported that he had been in contact with Emerson Babb regarding the contract with the University of Minnesota Press to publish volume 4 of *A Survey of Agricultural Economics Literature*. Because of the changes and time delay in getting this volume to print the press is no longer able to publish the book at the agreed-upon rate, and would need up to an additional $3,500, which amount could be deducted from earned royalties from the book. Motion: Manderscheid moved to give Beneke permission to negotiate with Minnesota Press to reach amiable conditions to publish the book. Miranowski seconded. Motion carried.

34. Lona Christoffers of the business office reported that the foundation would be presenting the Waldo E. Grimes Club Charter to Marc Johnson, head of the Department of Agricultural Economics at Kansas State University of the Awards Program August 6. Christoffers reported that there are two appreciation clubs in progress right now, The Harry R. Wellman Appreciation Club and the Gerald R. Dean Appreciation Club.

35. Glenn L. Johnson, Jim Bonnen, and Fred Buttell reported on Phase III of the Social Science Agricultural Agenda Project (SSAAP). The Phase III presentations have been very useful in preparing SSAAP publications. They presented a proposal for a pre- or postconference to be held at the 1991 summer meeting in Manhattan, Kansas, entitled "Multidisciplinary Workshop on Results from the Social Science Agricultural Agenda Project." Batie responded that the AAEA agreed to cosponsor this event at the Kansas meeting.

36. The proposed agenda for the annual business meeting was accepted as printed.

37. The written report from Lynn W. Robbins, chair of the Agribusiness Committee, was discussed. Activities of the committee over the last year included the WRCC meeting held in Las Vegas to discuss issues relating to agribusiness, and an informal review of the Adaptive Planning Committee report.

38. The written report from Kim Reda-Wilson, chair of the ad hoc Committee on Economic Education, was discussed. The committee unanimously agreed that a working relationship between AAEA and the JCEE would be mutually beneficial. The ad hoc committee requests that an invited paper session on economic education be included in next year's AAEA annual meeting. It is also suggested that a followup AAEA Committee on Economic Education be selected with a guaranteed three-year appointment, to allow for long-range planning.

39. The written report from John P. Nichols, chair of the Committee on Employment Services was discussed. A new "Careers For the Future" brochure has been produced, with Cathy Hamlett (Penn State University) as chair of this subcommittee. Don Ethridge, chair of a subcommittee to survey the agricultural economics departments, reported that results of the survey will be summarized and disseminated at a later date. Credit was given to Jaye Stefani of the AAEA Business Office, who provides the leadership for the Employment Center activities.

40. A written report by Kirby Moulton, chair of the Extension Committee was discussed. He pointed out the various extension activities planned for the Vancouver meeting, and stated that progress has been made in stimulating Extension members' interest in participation in AAEA activities.

41. A written report by George Hoffman, chair of the Industry Committee, was discussed. The primary activity of the committee over the past year has been the development of two programs for the summer meeting: The industry outlook session and the industry banquet. Hoffman made suggestions as to how the Adaptive Planning Committee report would fit in with the industry group and also made comments regarding the dues structure currently being utilized for industry memberships.

42. A written report by Alan Baquet, chair of the Information Retrieval Committee, showed that the committee had secured ten travel grants from Farm Foundation for reference room personnel to attend the AERO workshop along with several committee members. Also, an organized symposium at the Vancouver meeting on end user computing had been organized.

43. A written report by Vince Cusamano, chair of the International Committee, indicated this committee was instrumental in organizing the international banquet at the 1990 meeting and in promoting the organization of symposia and invited papers on international topics of interest to the committee and the association. The committee has also taken the lead in organizing the AAEA travel grants program to the 1991 International Agricultural Economists Association meeting in Tokyo.

44. A written report from Lionel Williamson, chair of the Committee on Opportunities and Status of Blacks in Agricultural Economics, indicated that a revision of the *Directory of Black Agricultural Economists* is being disseminated, along with the new brochure on *Outstanding Black Agricultural Economists*. Williamson reported that the proceedings of the preconference program held at Southern University in 1989 should be ready for distribution by late summer.

45. A written report of the Resident Instruction Committee submitted by Dorothy Comer, chair, explained the progress being made on a special symposium on graduate programs in agricultural economics in the United States and Canada. The committee plans to meet in Vancouver to set goals and identify specific assignments.

46. A written report of the Tellers Committee, chaired by Dan Otto, was reviewed, showing the following results for 1990–91: president-elect Bruce R. Beattie; director Brady J. Deaton; and director Katherine H. Reichelderfer. Foundation Governing Board members are Bruce F. Johnston and John E. Lee, Jr.

47. A written report by LeRoy Hushak on the Council of Professional Associations on Federal Statistics (COPAFS) was reviewed. He reported continued work on data issues, work on new bylaws and articles of incorporation, and active participation in COPAFS activities. He thanked the board for providing $1,000 of support for travel in 1990 and hopes this support will continue in 1991. MOTION: Perrin moved the board continue to provide $1,000 support for Hushak for 1991. Armbruster seconded. Motion carried.

48. A written report by Dan Tilley, chair of the Membership Committee, was reviewed. Items regarding *CWAE Newsletter* subscription charges and changes in foreign postage charges had been addressed by the board earlier in the meeting. The membership report showed membership fell approx-

imately 10% from 1987–89. The role of the membership committee in 1990–91 will be to develop and implement a marketing plan for AAEA.

49. Sam Cordes, chair of the 1990 Poster Committee, appeared before the board to report on the progress on the poster session project. Cordes reported that he encountered no major difficulties in arranging for the poster sessions. He indicated that seventy-nine proposals were submitted. This compares to thirty-nine submissions in 1989. Of the seventy-nine proposals submitted and evaluated, fifty-two or 65.8% were accepted. Cordes believes that poster session activity is not as challenging as it might be because there is a perception among some people that poster presentations are not appropriate for some types of work in the profession, such as highly rigorous theoretical approaches and complex empirical work. Cordes thinks that it is precisely the latter type of work which lends itself particularly well to a poster presentation. Cordes reported that 1990 was the third year for poster presentations and the second year that poster proposals were selected on a competitive basis. He said that in his judgment the poster sessions ought to have a prime time spot on the association's program agenda and also that the posters should be located in a high traffic area. Both of these conditions obtained for the 1990 meetings. He suggested particular attention be given to time and location, particularly until the poster concept is firmly established as an integral part of the annual program. Carsrud reported that a number of poster presentations required that a computer be included in the exhibit. She indicated that the cost of supplying all of the computers requested had been prohibitive in 1990 and urged that in subsequent years entrants be required to supply their own computing facilities for their exhibits.

50. Steve Sonka reported as chair of the AAEA Awards Committee. Sonka points out that a large number of nominations are submitted each year, and each receives thorough evaluation from members of the profession. Sonka believes that this process has now been refined to the point where it operates smoothly. He pointed out that the Quality of Communication and the Distinguished Policy Contribution categories offer a special challenge because of the diversity of materials which are typically presented within these categories. The fact that committee members or evaluators are faced with the difficult task of comparing different forms of media, for example books versus multimedia presentation, complicates the process as does the fact that individual efforts must sometimes be compared with the same efforts of a group of scholars. He indicates that one possibility would be to have both group and individual awards given in some categories. Sonka indicated that there was ambiguity as to whether AAEA membership is a requirement for an entry in the awards program. He expressed concern over the relatively small number of nominees in some categories; in particular, the Distinguished Extension and the Distinguished Policy Awards have relatively small numbers of entries. He believes that it is important to continue to publish the number of entries in all categories so that association members can have better information about the likelihood of success within different categories.

51. CWAE requested that arrangements be made on the AAEA membership forms for a $5.00 subscription fee to be added for those members who wish to receive the *CWAE Newsletter*. MOTION: Armbruster moved that the membership application and renewal form include as an option the $5.00 subscription fee for those members who wish to receive the *CWAE Newsletter*. Perrin seconded. Motion carried.

52. Perrin passed out a revised budget for 1990 and a proposed budget for 1991. Beneke went through the budget item by item. Minor modifications were made by the board. MOTION: Perrin moved that the board approve the revised budget for 1990 and the proposed budget for 1991. Armbruster seconded. Motion carried.

53. Raymond Beneke, secretary-treasurer, reported that the endowment created by astute financial management on the part of our predecessors and a rising stock market has enabled the organization to support generously two exciting projects, the foundation and *CHOICES* magazine, without subjecting the financial health of the association to unacceptable risks. One trend which has been obvious is the increasing resistance we as an organization face in attempting to coax subsidies from other organizations to support association activities. We see this in asking board members and others serving the association to obtain funds for travel expenses, as well as enticing universities to host our annual meeting. The business office staff continues to serve creatively and diligently. Beneke reported that as a group they thrive on responsibility and welcome new challenges.

54. Before adjournment, past president Manderscheid and retiring board members Perrin and Miranowski shared their thoughts with the board on the occasion of their having completed their three-year term. Manderscheid indicated that he would be leaving the board after having served six of the past eight years. All three wished the board success in their future deliberations and expressed their appreciation for the opportunity they had been accorded to serve on the board.

The meeting was adjourned.

Respectfully submitted,
Raymond R. Beneke, secretary-treasurer

Minutes of the AAEA Foundation Governing Board Meeting Vancouver, British Columbia, Canada, 5 August 1990

Present: Voting members:
Armbruster, Brake, Castle, Farrell, Kinsey, Manderscheid, Perrin, Sundquist, and Swackhamer

Absent:
Seevers

Members ex officio:
Beneke

Guests:
Christoffers, Lee

The meeting of the Governing Board of the AAEA Foundation was called to order at 5:30 p.m. in the North Committee Room of the Walter Gage Complex on the campus of the University of British Columbia. President Emery Castle welcomed the newly elected board member, John E. Lee, Jr. The other new board member, Bruce Johnston, was unable to attend.

Castle gave a brief report on the state of the foundation. After five years of operation, activities continue at an accelerated rate in both the program and finance categories. The foundation is pleased to report that eight $500 grants were made to support minority travel to Vancouver. In addition, student grants totaling $1,600 were provided for travel to Vancouver. The Waldo E. Grimes Club was chartered at the fall 1989 meeting of the foundation board and the certificate of charter will be presented to Marc Johnson, head of the Department of Agricultural Economics at Kansas State University at the Awards Program August 6.

Walter Armbruster announced that the AAEA would be sponsoring eight $1,500 travel grants to attend the International Conference of Agricultural Economists in Japan in August 1991. It was suggested that it would be a suitable project for the foundation to sponsor additional grants to the conference in Japan. MOTION: Armbruster moved the foundation allocate two or more travel grants of $1500 each for minority professionals to attent the international conference in Japan in 1991. Kenneth Farrell seconded. Motion carried. Farrell and Burt Sundquist will work on a modification of previous travel grant guidelines and criteria for publication in the September *Newsletter* with recommendations on details at our November meeting. Farrell and Sundquist also agreed to coordinate this activity with the AAEA International Committee.

Lester Manderscheid gave the report of the Nominating Committee. Officers nominated for 1990–91 include Ken Farrell, president; Burt Sundquist, vice-president–programs; and Larry Boger, vice-president–finance. MOTION: Manderscheid moved we approve this slate of officers by unanimous ballot. Motion seconded. Motion carried.

Castle expressed his thanks to Jean Kinsey, who is retiring from the board, for her dedication and service over the past three years, and also to Gene Swackhamer and Larry Boger for their fund-raising efforts. Control of the meeting was turned over to the newly elected president, Ken Farrell.

Farrell announced that the fall board meeting would be 2–3 November 1990 in either Kansas City or Minneapolis. Raymond Beneke announced that he and the business office were preparing revised financial statements for presentation at the fall meeting. Farrell and Armbruster will present a report on appreciation club guidelines for the board's review.

Respectfully submitted,
Raymond R. Beneke, secretary-treasurer

Minutes of the Annual Business Meeting, Vancouver, British Columbia, Canada, 6 August 1990.

President Sandra S. Batie called the meeting to order at 8:00 a.m. in the War Memorial Gym on the campus of the University of British Columbia. The minutes of the 1989 annual business meeting, Baton Rouge, Louisiana, were approved as printed in the December 1989 *AJAE*.

1. Batie reported on the results of the election. Election material had been mailed out to all who had paid their 1990 dues by 1 April 1990. Elected were Bruce R. Beattie, Montana State University, president-elect; Brady J. Deaton, University of Missouri, director; and Katherine R. (Kitty) Reichelderfer, Resources for the Future, director. Bruce F. Johnston, Stanford University, and John E. Lee, Jr., ERS USDA, were elected members of the AAEA Foundation Governing Board.

2. Batie reported on a successful term of office as president of the association. (The complete report of the president appears elsewhere in this issue.)

3. Raymond Beneke gave the report of the secretary-treasurer. (The complete report of the secretary-treasurer appears elsewhere in the issue.)

4. Richard Perrin, chair of the Finance Committee, reported that the financial base of the association remains strong. However, Perrin emphasized that this picture of robust financial health is misleading and that large deficits are expected in 1991. Perrin moved the association raise its dues from $45.00 to $60.00 for regular membership with proportionate increases for the other categories of membership. The motion was seconded. There was no discussion. Motion passed. The revised 1990 budget and the 1991 budget were submitted to the members in attendance. Both budgets were approved without discussion, additions, or corrections. (A complete Finance Committee report appears elsewhere in this issue.)

5. Peter Barry, editor of the *American Journal of Agricultural Economics*, reported on the progress of volume 72 and other activities of the *AJAE* editor's office. He pointed out that the board had authorized a 10% increase in articles to be printed in order eventually to reduce the time between acceptance and publication of articles. (A complete report of the editor appears elsewhere in this issue.)

6. Lyle Schertz, editor of *CHOICES* magazine, reported that he would look with favor upon more

one- and two-page manuscripts being submitted for possible publication. He also indicated he would like to include material from a larger number of international authors. He reported that the joint Kellogg project between the AAEA and the AAEdA is facilitating the flow of material in *CHOICES* out to the press. (A complete report of the editor appears elsewhere in this issue.)

7. Mike Ellerbrock, editor of the *AAEA Newsletter*, reported that the transition of the newsletter editorship was made with a minimum of disruption and that the publication of the newsletter is progressing well. A new column is being developed for publishing eclectic essays and will be entitled "Making Connections." (A complete report of the editor appears elsewhere in this issue.)

8. Speaking on behalf of the AAEA Foundation Governing Board, Emery N. Castle, president, reported the foundation has assigned priority to supporting activities in the following areas: (*a*) *CHOICES* and communications, (*b*) minority professionals, (*c*) student development, and (*d*) international travel. Castle announced he would be presenting the Waldo E. Grimes Appreciation Club charter to Marc Johnson, head of the Department of Agricultural Economics at Kansas State University. (The AAEA Foundation report appears elsewhere in this issue.)

9. Lester V. Manderscheid read the proposed changes to the AAEA constitution: (change shown in bold print):

Article VI. Officers. Section 2 Appointed should read: "The executive board shall appoint a Secretary-Treasurer, an editor of the *American Journal of Agricultural Economics*, **an editor of *CHOICES* and an editor of the** *AAEA Newsletter*, all of whom shall serve for one-year terms and may succeed themselves in office."

Article V. Executive Board. Section 1 How Constituted shall read: "The Secretary-Treasurer, the editor of the *American Journal of Agricultural Economics*, **the editor of** *CHOICES*, and, upon designation by the executive board, the presidents (or designees) of any national or regional Associations, shall be members ex-officio (non-voting) of the executive board."

Manderscheid moved these changes be adopted. Motion seconded and carried.

10. Bruce R. Beattie, president-elect, read the following resolution:

RESOLUTION

Whereas the officers, members, families and guests of the American Agricultural Economics Association wish to recognize the efforts and warm hospitality of our hosts for the 80th Annual Meeting held at the University of British Columbia on 4 August to 8 August 1990.

Be it resolved that the American Agricultural Economics Association expresses its gratitude for this effort and hospitality to Rick and Marla Barichello and others affiliated with the Department of Agricultural Economics at UBC for assisting and advising local special events and activities and to the UBC Conference Staff members who have worked diligently with our business office staff to organize this year's annual meeting.

Be it resolved that the American Agricultural Economics Association expresses its appreciation to Charlene Carsrud, annual meeting coordinator; Lona Christoffers, business office coordinator; Jaye Stefani, employment center coordinator; and their associates in the AAEA Business Office, for their yeoman efforts in facilitating this meeting. Beattie moved that this resolution be accepted. The motion was seconded and approved.

11. Batie expressed her appreciation to the membership, the board, and the business office professionals, and presented the gavel to president-elect Warren E. Johnston.

12. Johnston recognized the retiring board members, Lester V. Manderscheid, John Miranowski, and Richard K. Perrin, for their service to the board and the association. He reminded the group of the ASSA meeting to be held in Washington, D.C., in December 1990, and issued an invitation to the membership to attend the 1991 annual meeting at air-conditioned Kansas State University in Manhattan, Kansas.

The business meeting adjourned.

Respectfully submitted,
Raymond R. Beneke, secretary-treasurer

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Subjects

Classification System

Agricultural Economics General; Curricula and Teaching; Extension, Profession

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Agricultural Products; Demand, Supply, Prices; Food, Consumer, and Household Economics

Marketing; Agribusiness; Cooperatives; Transportation; Industrial Organization; Vertical Coordination

National Resources; Energy; Conservation; Environment; Wastes; Land Use and Tenure; Recreation; Water; Fisheries

Production Economics and Management; Risk and Uncertainty

Public Issues and Policy: Agricultural Regulations; Taxation; Inflation, Welfare Programs; Poverty; Regional and Community Development; Education; Health

Research Methodology; Modeling; Econometrics; Mathematical Programming; Agricultural Data

Authors

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American Agricultural Economics Association

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Lawrence W. Libby, University of Florida
Katherine H. Reichelderfer, Resources for the Future

Objective

The American Agricultural Economics Association (AAEA) seeks to further the systematic development of knowledge of agricultural economics in order to improve agriculture and agriculture's contribution to the general economy.

AAEA

—publishes the *American Journal of Agricultural Economics*, the *AAEA Newsletter*, *Choices*—The Magazine of Food, Farm, and Resource Issues, and, periodically, a *Handbook-Directory* of AAEA members;
—plans and conducts an annual meeting of the membership;
—sponsors awards for Distinguished Undergraduate Teaching, Distinguished Extension Programs, Distinguished Policy Contribution, Publication of Enduring Quality, Outstanding Journal Article, Quality of Communication, Quality of Research Discovery, Outstanding Master's Thesis, and Outstanding Ph.D. Dissertation;
—recognizes prominent agricultural economists as Fellows;
—operates the AAEA Employment Service for agricultural economists.

Membership and Subscriptions

AAEA is a professional society for agricultural economists and others who are interested in agricultural economics. A nonprofit organization, AAEA is committed to furthering knowledge about the economics of agriculture, rural communities, and natural resources.

Membership in the AAEA will bring you *Choices*, the *AJAE*, the *AAEA Newsletter*, and other occasional AAEA publications, permit you to use the AAEA Employment Service, and allows you to attend the annual meetings.

Calendar year dues are: $45, regular members; $22.50, senior (retired and 65) and junior (student) members; $67.50, family members; $150, industry members. Lifetime membership is available for members who are at least 55.

Subscription prices: *American Journal of Agricultural Economics*—$65 per year ($73 overseas); single copies, $14.50. *Choices*—The Magazine of Food, Farm, and Resource Issues—$32.50 per year ($52.50 overseas); single copies, $10. *AAEA Newsletter*—$12 per year ($17 overseas).

For further information about the American Agricultural Economics Association, contact the AAEA Business Office, 80 Heady Hall, Iowa State University, Ames, Iowa 50011-1070 (515-294-8700).